

THE EFFECT OF AN ELECTROMAGNETIC PULSE STRIKE ON THE  
TRANSPORTATION INFRASTRUCTURE OF KANSAS CITY

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MASTER OF MILITARY ART AND SCIENCE  
Homeland Security Studies

by

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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

## ABSTRACT

THE EFFECT OF AN ELECTROMAGNETIC PULSE STRIKE ON THE  
TRANSPORTATION INFRASTRUCTURE OF KANSAS CITY, by Major Patrick J.  
Reardon Jr., 106 pages.

In the twenty-first century many non-state actors and third-rate countries aspire to become relevant in a world moving forward. The development of Electromagnetic Pulse (EMP) used as a weapon poses a significant threat to an electrically driven world. An EMP strike is an extremely desirable way to affect a given population of any nation. Due to the indirect nature of an EMP strike, its employment has minimal signature further concealing its origin or motivated actor. An aspiring third-rate country could harness or employ this weapon to quickly ensure its relevancy in the world, while a world super-power could use it to upset the balance of power without bringing attention to its self. As the U.S. and specifically a mid-sized city such as Kansas City adjust for tighter homeland security, they also look to combat potential future threats. Kansas City is at the epicenter of U.S. transportation acting as a major mid-continent hub for multi-mode transport, where everything is executed just in time. This study examines how an Electromagnetic Pulse (EMP) strike targeting Kansas City will affect its road, rail, and distribution infrastructure.

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## ACRONYMS

ABS	Anti-Locking Braking System
CIKR	Critical Infrastructure and Key Resources
DCS	Digital Control Systems
DOD	Department of Defense
ECM	Electronic Control Module
EFI	Electronic Fuel Injection
EMP	Electromagnetic Pulse
HEMP	High-Altitude Electromagnetic Pulse
HMI	Human Machine Interface
ISO	Independent System Operator
ITS	Intelligent Transportation Systems
JTF	Joint Task Force
MTU	Master Terminal Unit
NSHS	National Strategy for Homeland Security
NYC	New York City
PLC	Programmable Logic Controllers
RFID	Radio Frequency Identification
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition systems
TMC	Traffic Management Center
U.S.	United States



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## CHAPTER 1

### INTRODUCTION

You and I have a rendezvous with destiny. We will preserve for our children this, the last best hope of man on earth, or we will sentence them to take the last step into a thousand years of darkness. If we fail, at least let our children and our children's children say of us we justified our brief moment here. We did all that could be done.

— Ronald Regan, *Campaign address for Goldwater Presidential Campaign*

#### The Problem

In the twenty-first century many non-state actors and third-rate countries aspire to become relevant in a world moving forward. The emerging development of an Electromagnetic Pulse (EMP) weapon poses a great threat to an electrically driven world, and an aspiring third-rate country could harness and or employ this weapon, quickly ensuring its relevancy in the world. As the United States (U.S.) and specifically a mid-sized city such as Kansas City adjust for tighter homeland security, they also look to combat unforeseen threats from those who may seek to impose their will. Kansas City is at the epicenter of U.S. transportation, acting as a major mid-continent hub for road transport, rail transport, and distribution operations. With a medium size population of well over 600,000, Kansas City represents itself as the norm for cities across the U.S. in its same class.

Transport in Kansas City is dedicated locally and nationally with major road, rail, and distribution networks connecting through this vital hub. Understanding the transportation implications associated with a naturally occurring or man-made EMP strike against Kansas City will provide an application based perspective and analysis,

which could be applied to other cities across the U.S. in the same class. While research has been conducted into EMP effects it has for the most part not been applied against transportation for analysis. This research will help to identify second and third order effects on society and loss of transportation, opening areas for further research. This research will also provide insight from an observer's perspective to gain an overall idea of how an EMP will affect mid-size U.S. cities from a transportation perspective.

Investigating how an EMP will affect a mid-size city, by focusing on Kansas City's road and rail based transportation distribution infrastructure, will provide a foundation for understanding the potential transportation implications on a local, national, and global scale. The researcher aims to provide the reader a detailed analysis to enlighten the reader towards further research into the effect of an Electromagnetic Pulse strike on society, transport, and the potential impacts of a loss of power in relation to them.

#### Primary Research Question

How will an Electromagnetic Pulse (EMP) strike targeting a mid-size city such as Kansas City affect its road and rail based transportation distribution infrastructure?

#### Secondary Research Questions

In order to accurately answer the primary research question, one secondary question is addressed. This question will help understanding the broader problem, while capturing further ramifications of an EMP affecting transport infrastructure. The secondary research question asks what are the second and third order effects if a city's transportation and distribution networks are shut down?

### Key Terms

To provide a better understanding of the content in this thesis certain key terms are defined. These terms and or words are used throughout the research paper and are common within the topics of electromagnetic pulse and transportation.

Demand: The rate at which electric energy is delivered to consumers or by a system or part of a system, generally expressed in kilowatts or megawatts, at a given instant or averaged over any designated interval of time (U.S.-Canada Power System Outage Task Force 2004, 216).

Digital Control System: A digital computer used for real-time control of a dynamic system, usually in an industrial environment, as part of a Supervisory Control and Data Acquisition (SCADA) system. A DCS samples feedback from the system under control and modifies the control signals in an attempt to achieve some desired behavior. Analysis of such digital-analogue feedback systems can involve mathematical methods such as difference equations, lap lace transforms, z transfer functions, state space models and state transition matrices (Dictionary.com 2014, 1).

Electromagnetic Pulse: An electromagnetic pulse (EMP) is defined by the Technology Division of the National Communications System as a wide frequency range, high-intensity, extremely rapid, and short duration burst of electromagnetic energy which produces electric and magnetic fields which can couple to metallic conductors associated with electrical and electronic systems to produce damaging current and voltage surges (Riddle 2004, 2).

Flash over: A plasma arc initiated by some event such as lightning. Its effect is a short circuit on the network. (U.S.-Canada Power System Outage Task Force 2004, 217).

Grid: An electrical transmission and or distribution network (U.S.-Canada Power System Outage Task Force 2004, 215).

High-Altitude Electromagnetic Pulse: A nuclear warhead detonated hundreds of kilometers above the Earth's surface is classified as a high-altitude electromagnetic pulse (HEMP) device. The effects of a HEMP device depend on factors including the altitude of the detonation, energy yield, gamma ray output, interactions with the Earth's magnetic field and electromagnetic shielding of targets (Riddle 2004, 1).

Interconnected System: A system consisting of two or more individual electric systems that normally operate in synchronism and have connecting tie lines (U.S.-Canada Power System Outage Task Force 2004, 218).

Programmable Logic Controller: A programmable microprocessor-based device used in discrete manufacturing to control assembly lines and machinery on the shop floor as well as many other types of mechanical, electrical and electronic equipment in a plant. Typically programmed in an international programming language, a PLC is designed for real-time use in rugged, industrial environments. Connected to sensors and actuators, PLCs is categorized by the number and type of ports they provide and by their scan rate (Davis 2014, 1).

Supervisory Control and Data Acquisition systems: Are electronic control systems used for data and acquisition and control over large and geographically distributed infrastructure systems. They are used globally as electronic transmission and distribution systems (Electromagnetic Pulse Commission 2008, 1-2).

Transformer: A device that operates on magnetic principles to increase step up or decrease step down voltage (U.S.-Canada Power System Outage Task Force 2004, 220).

### Significance

The U.S. tested the effects of an EMP in the early 1960's during Operation Starfish, which tested the detonation of a nuclear device at an altitude of 400km above Johnston Island in the Pacific. The Hawaiian Islands, 1400 miles away from the blast reported electrical system malfunctions with the effect of circuit breakers tripping, street lights failing, and a telecommunication relay rendered inoperable (Graham 2008, 1). The Commission to Assess the Threat to the United States from Electromagnetic Pulse Attack concluded in 2008 hostile state actors and non-state actors could conduct an EMP attack against the U.S. within the next 15 years. This assessment was based on their investigation of potentially hostile states and or non-state actors that could or have acquired nuclear weapons and ballistic missiles (Carafano 2010, 3).

An EMP as a weapon is an extremely desirable way to affect a given population of any nation. Due to the inherent nature of an EMP strike, its employment is for the most part indirect. With little to no signature it can strike, without revealing its origin or motivated actor. In a world riddled with terrorism, the terrorists themselves are wary of revealing themselves because the eyes and ears of the world are attempting to sensor and intercept their every move. Wary of a drone strike causing their imminent death, terrorists, non-state actors, and third-rate states such as North Korea are inclined to use indirect means as a way to achieve their goals.

An EMP strike can benefit the motivations of any nation seeking to incite chaos, and fear. Without revealing their actions they could use an EMP to disrupt any nation, also potentially creating a second order effect of death within the targeted population. The population of the affected area would degrade and destroy itself through its over

reliance on power and technology if not responded to properly. An EMP strike could look like a system wide electrical failure caused by a natural occurrence, while ultimately its origins are the indirect result of another world superpower hoping to incite fear and chaos to redirect the will of the affected nation. Disorder from the effect is seen during the New York City Blackout of 1977, where two lightning strikes overloaded substations with an E2 type pulse crippling power lines, transformers, and service cables. New York City was without power for an entire day, costing an estimated 346 million, including some 3000 arrests during this period (SCI 1978, 3, 14).

Due to the United States' over reliance on technology, it inherently is dependent on energy, microprocessors, and transformers. This over reliance is seen in the transportation world, where everything is executed just in time. Most post 1970's vehicles have Electronic Fuel Injection which controls fuel through microchip processors. Most modern day vehicles have an on board computer system which again has microprocessors. Railcar switches change tracks at the flick of a switch also rely on microprocessor transactions and transformers to carry out commands. Nearly every piece of transportation in the U.S. and specifically Kansas City use electricity, microprocessors, and or transformers making an EMP strike not only devastating, but also deadly. The gap this study intends to fill is how will an Electromagnetic Pulse (EMP) strike targeting Kansas City affect its surface transportation infrastructure?

### Assumptions

The facts collected from the; Commission to Assess the Threat to the United States from Electromagnetic Pulse Attack, National Communications System, The Heritage Foundation, and civilian research regarding electromagnetic pulse are true.



These factors must be accepted as fact to conduct any analysis into the effect an EMP strike may have on Kansas City's transportation infrastructure. In addition, it is assumed the Kansas City surface transportation and distribution networks are not hardened to protect against an EMP strike.

### Limitations

The number one limitation is time. This study will compile research over a span of only eight months looking at documents dating from the present to the 1950's. This thesis will represent only the data collected during these eight months. A second limitation is the small amount of research conducted on Electromagnetic Pulses directly effecting transportation, thus resulting in this study's assumption of how an EMP will affect electrical grids in relation to electrical infrastructure found on transportation assets. This research is limited to the Kansas City area for scope and time. By understanding the result of a mid-sized city the resulting will allow for application on a broader global scale.

### Delimitations

A delimitation will be scope due to time. This study will only apply an EMP strike to surface transportation infrastructure. There are many other factors that an EMP could affect like air transportation, electrical grids, and communications platforms not addressed within the focus of this research. The second delimitation is location. In an effort to use Kansas City as a case study, other physical locations are not considered directly due to time. Other researchers may apply conclusions presented within this research to help understand the effect on other similar mid-sized cities. Lastly, this

research paper will only address information provided in the unclassified domain. The researcher acknowledges there is a high probability that research material on this topic is held in the classified domain.

### Background

The following sections will provide brief information on what an EMP is and its resulting effect. This will provide a base foundation to assist in understanding the effect an EMP threat will pose to surface transportation infrastructure. This section will also help to frame Kansas City in terms of transportation and its relation as a critical transportation hub in the U.S.

### Electromagnetic Pulse

An Electromagnetic Pulse is created by either a thermonuclear device exploded in the upper atmosphere of earth or a naturally occurring event caused by solar interference. In the case of a man-made thermonuclear device being detonated in the upper atmosphere the resulting explosion emits gamma rays. These gamma ray particles rapidly accelerating, and become charged as they fall back to earth. These charged particles disrupt electronic systems by sending an unregulated amount of voltage through circuits, essentially overcharging and frying conduits, micro-processors and capacitors not built to withstand such a charge (Baker 2007, 2, 3). This specific example is commonly known as High-Altitude Electromagnetic Pulse (HEMP).

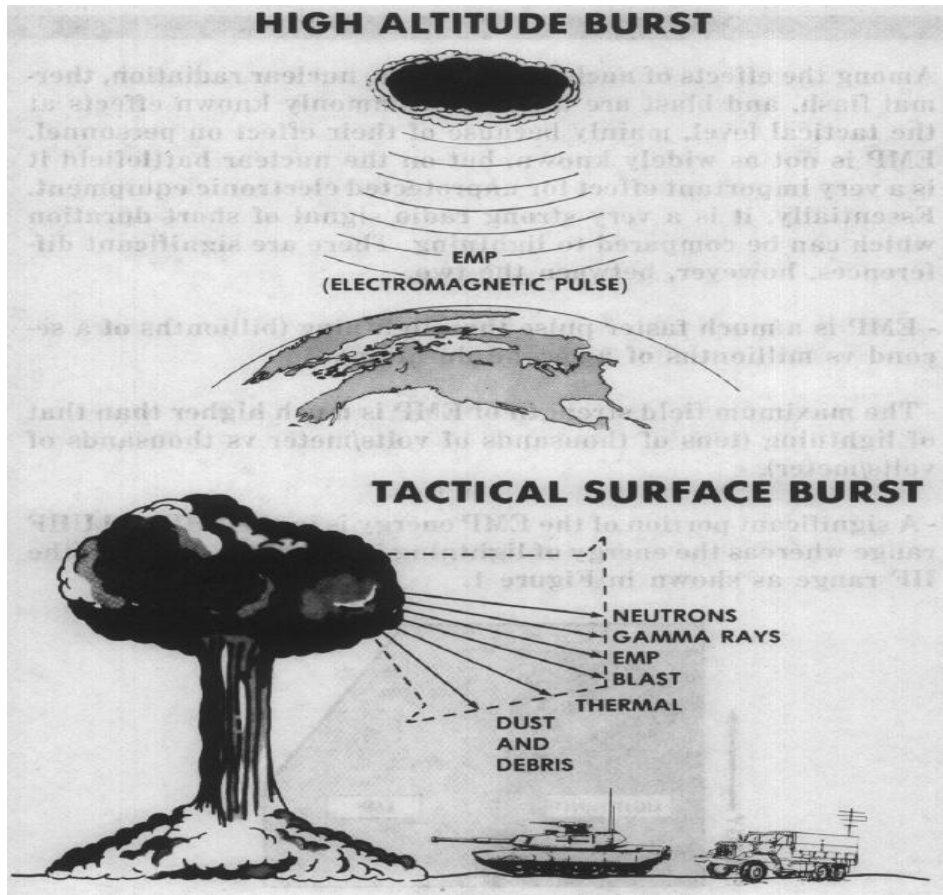


Figure 1. Comparison of high altitude burst and surface burst

Source: U.S. Army Nuclear and Chemical Agency, *EMP Mitigation for Field Equipment*, Commander's Nuclear and Chemical Flash Bulletin, CB-018583.01 (Fort Belvoir, VA: U.S. Army Nuclear and Chemical Agency, May 1985).

The higher in the earth's atmosphere the thermonuclear device detonates the larger the distance of the effect becomes. At an altitude of 40km or above an EMP gains its greatest effect, unleashing high energy nuclear radiation particles over a larger volume of atmosphere. The explosive yield of a nuclear weapon is not as critical as the design. A device of less than 10 kilotons can have a greater EMP effect range than a crudely designed weapon in the megaton range if it is employed correctly (Riddle 2004, 2).

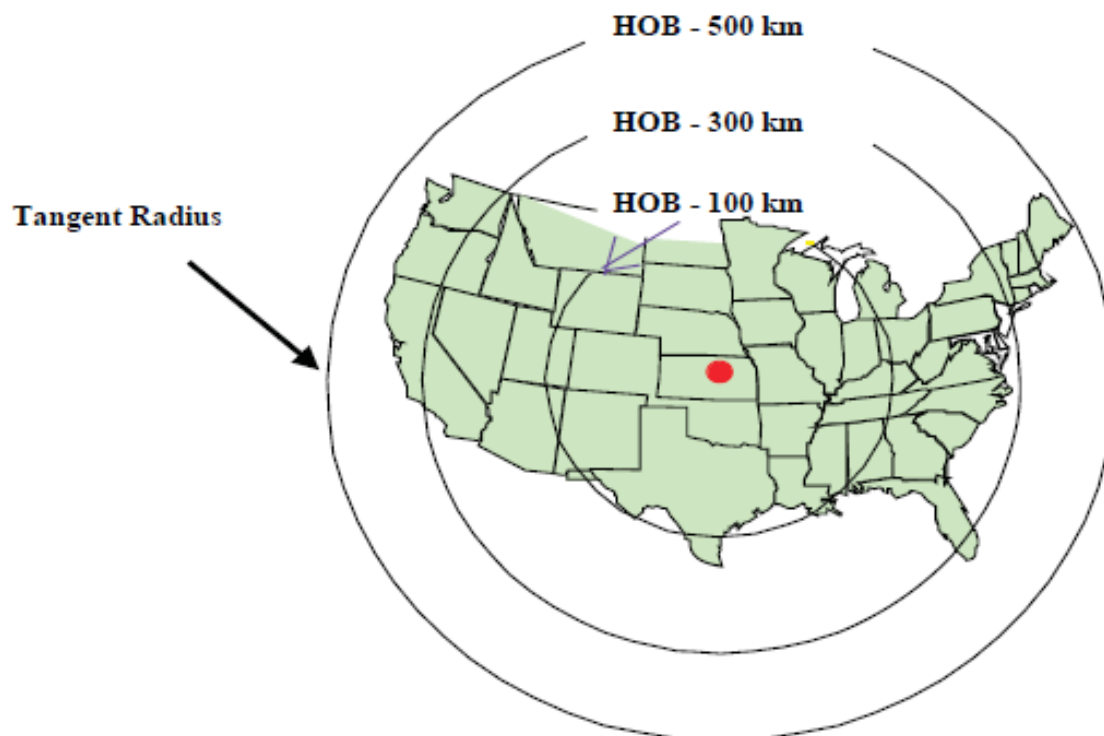


Figure 2. Single High Altitude Detonation EMP Ground Coverage for 3 Heights of Burst (HOB)

*Source:* George H. Baker, “EMP: A National-Scale Threat to the U.S. Infrastructure,” The Critical Infrastructure Protection Report, [http://works.bepress.com/george\\_h\\_baker/6](http://works.bepress.com/george_h_baker/6) (accessed 15 October 2013).

There are three categories of electrical pulse charges listed in order of sequential effect named E1, E2, and E3 respectively. An E1 pulse charge strikes first and is the most elusive form of electrical shock which occurs in a fraction of a second. In a near simultaneous time frame it disrupts and destroys electronic systems through initial “Shock”. An E1 pulse will destroy consumer electronics, and un-hardened EMP equipment if not properly shielded. Any electronics devices connected to an antenna which receive an electronic signal cannot be shielded against and E1 pulse, regardless of any EMP shielding efforts (Wilson 2008, 13).

The second type of charge is an E2 pulse, which is the same effect as being struck by natural lightning. It produces a greater degree of damage to electronic infrastructure, but is easier to protect against. Most electrical components have built in or added protection against lightning strikes, which mitigate damage to connected systems. An example of this is a surge protector, which is commonly connected to home and office electronics to prevent electrical surge damage from a lightning strike. An E2 pulse strikes a fraction of a second after an E1 pulse. E1 pulses circumvent normal protection measures as such home surge protectors, essentially leading the way for E2 pulses to greatly further damage systems (Electromagnetic Pulse Commission 2008, 6).

The tertiary charged particle is called an E3 which is a longer duration pulse lasting for around one minute. An E3 pulse is an electromagnetically distorted wave, propagated in the atmosphere. This pulse can closely resemble the effect of a geomagnetic storm, like the Aurora Borealis found in Alaska. E3 pulses resonate along a greater distance and have a greater damaging effect against power lines, electrical cables, and transformers. E3 pulses literally go the distance following E1 and E2 pulses, knocking out remaining connected electronic infrastructure (Electromagnetic Pulse Commission 2008, 6).

The sequential timing and coupling of these three pulses one after another produces the damaging effect of an EMP. Each pulse destroys or bypasses efficiently allowing further damage of electrical systems. The sequential timing of the effect can cause a catastrophic effect over a wide area in a fraction of time. The coupling effect of all three pulses known as an EMP has the potential to decimate modern day electronic

infrastructure, potentially shocking mankind into the dark ages (Electromagnetic Pulse Commission 2008, 6).

### Kansas City Transportation

A vast component to the United States economic strength resides in its ability to transport domestically. Intercity and local trucks transport nine billion tons of freight annually. The U.S. trucking industry generates over \$606 billion annually, which is around 5 percent of the United States Gross Domestic Product. In addition to the U.S. trucking industry, the U.S. Rail industry also receives \$68 billion annually in freight revenue. Of railroad tons transported in the U.S., 41 percent is energy producing coal (Association of American Railroads 2013, 1).

Kansas City proper, to include the Missouri and Kansas cities, geographically sits at the nation's crossroads connecting the Atlantic to the Pacific. It is a premier surface transport node for the U.S. connecting commercial trucking to commercial railways, while interchanging many people across the vast interstate highways. Approximately 650,000 people live across 438 square miles in Kansas City, averaging around 1,200 people per square mile, as of the 2010 U.S. Census (U.S. Census Bureau 2013a, 1; U.S. Census Bureau 2013b, 1). Kansas City alone manufactures and ships 16 million dollars of goods annually (U.S. Census Bureau 2013c, 1; U.S. Census Bureau 2013d, 1).

A Kansas City citizen travels on average 28 minutes to and from work each day. 228,000 rely on their own individual transportation, while 29,000 carpool each day to reach their work destination. Around 9,000 people rely on public transport to help them get to work each and every day (U.S. Census Bureau 2013c, 1; U.S. Census Bureau

2013d, 1). Kansas City's public and commercial reliance on surface transportation is immense, just-in time, without room for error.

### Summary

The effects of one natural or man-made EMP strike could devastate the citizens and commercial industry of Kansas City. The lasting residual effects could not only bring surface based transportation to a halt, but also leave close to a million people without a way to get to work, get to the store to buy food, or utilize transportation based essential services. In an age when technology and energy are our greatest assets, they are also our greatest crutch. As transportation across the U.S. tries to out pace its own technological prowess to compete in an ever evolving market, resistances or vulnerabilities are often overlooked. From a transportation perspective Kansas City is one of the nation's greatest transportation hubs, connecting the Atlantic Ocean to the Pacific, and Mexico to Canada. The sheer volume of cargo transiting the Kansas City area creates a significant vulnerability that an EMP strike could directly affect, with the resulting effect rippling across the nation, and shocking its transportation infrastructure into submission.

## CHAPTER 2

### LITERATURE REVIEW

The purpose of this literature review is to evaluate existing literature relevant to the thesis and identify any gaps in the timeframe provided. This study will break the research down into two areas with one being topics, and the other case studies. The topics include five distinct areas and the first is Electromagnetic pulse with review into three specific employment methods; natural, conventional weaponry, and unconventional weaponry. The second is highway transportation with three focus areas of; prime movers, road infrastructure, and control. The third research area is rail transportation through three focus areas of; engines, rail infrastructure, and control. Research into SCADA systems is the fourth topic with focus on what they are and do. Finally the last topic is a brief look into Kansas City's surface transportation and distribution use.

The second area is a literature review of case studies that exhibited characteristics of EMP effects to help provide context, correlations, and a basis for creating an impact theory in relation to Kansas City transport infrastructure. The first case study will review literature of the US Department of Defense Operation called Starfish Prime conducted in the 1960s. The second case study will look into the events surrounding the 1977 New York City Blackout. The final case study will review literature from the 2003 North East Blackout.

These areas will be discussed with electrical emphasis to highlight impact in relation to the problem. A review of research into these areas indicates research was not conducted into this specific scenario. To the authors knowledge no research has



specifically addressed how an EMP strike will effect a mid-sized city such as Kansas City's surface transportation infrastructure.

### Electromagnetic Pulse

The study of electromagnetic pulse technology affecting infrastructure is not new, and has yielded results concurrent with our knowledge of the effects dating back to the 1950's. The specific study of an EMP's effects on transportation lacked application of investigation. As a result, there are numerous articles, texts, and journals written which focus on the effects of electromagnetic pulse, to include EMP affects against the U.S.'s electrical infrastructure. A preliminary review of research material indicates a significant gap of its affect on U.S. transportation infrastructure. A significant number of documents yielded volumes of congressional testimony, a U.S. congressional commission's findings, and U.S. Department of Energy and U.S. Department of Defense research into electromagnetic pulse technology. These documents help to provide context and understanding for the application of EMP on transportation infrastructure. Additional research uncovered different employment methods of an EMP which are natural means, conventional weaponry employment, and unconventional weaponry employment.

A U.S. D.O.D. operation code name Starfish Prime detonated a nuclear weapon in the upper atmosphere above Johnston Island in the Pacific during the 1950s. The resulting pulse affected the Hawaiian Island chain 1400 miles away. The islands reported electrical system malfunctions with circuit breakers tripping, street lights failing, and a telecommunication relay rendered in operable (Graham 2008, 4). The effect is known as Electromagnetic Pulse. An EMP is created from a high altitude detonation of a thermonuclear device. This high intensity burst creates gamma rays and at an altitude of

40-400km above the earth's surface produces charge electrons falling back to Earth. The resulting current produced essentially rains down coupled shockwaves of electrically charged particles in sequence, of which the coupling electric wave destroys electronic equipment (Carafano 2010, 3).

The threat of an EMP attack against the U.S. is difficult to assess, however there are some indications that EMP threats are growing largely due to worldwide access to newer technologies and the proliferation of nuclear weapons. Like the Cold War, mutually assured destruction proved to deter aggression against the exchange of nuclear arsenals. However, even one low-yield nuclear device launched and detonated in the upper atmosphere could produce an EMP effect which could result in the destruction of electronics without direct fatality. The U.S. may place a national priority of effort on trying to save lives instead of locating the origin of the effect. The residual indirect effects would produce fatalities, as opposed to the direct effect. Conducting an attack against the U.S. indirectly is an incentive for other countries to invest in nuclear EMP technology (Wilson 2008, 1).

The effect of an EMP has perked many people's thoughts to include that of the U.S. Congress, which launched a commission to, "Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack". The commission reported in 2008, thorough analytical testing and activities, that an EMP places the U.S. society at risk of catastrophic consequences. The commission concluded in general that an EMP attack against our national civilian infrastructure is a serious problem, and one that the U.S. will face into the future (Electromagnetic Pulse Commission 2008, 11).

Electromagnetic pulses are found within nature, its self in the rudimentary form of lightening and to a greater degree looks like the Aurora Borealis effects in Alaska. In 1977 two lightning strikes overloaded the electrical substations of New York City creating a blackout across the entire city. The lightning strikes closely resemble the previously discussed E2 EMP level of effect, causing the Indian Point power plant north of New York to fail, power lines rendered useless, and transformers blown in the area. The New York blackout of 1977 only lasted one day but cost in upwards of \$346 million in damages with the bigger price resulting in the arrest of 3,000 citizens in one 26 hour period (SCI Controls 1978, 3, 14). Electricity showed to be the fine fabric of social order that seemingly held this city together, in this case it came unraveled. Vast looting commenced across the city of New York when citizens learned of the blackout. Local law enforcement could not control the masses nor the near immediate breakdown of social order that ensued. Law enforcement lost control and could only spectate from an outmatched position with no chance of stopping the massive chaos throughout the city, as a result of two natural lightning strikes (Newsweek 1977, 1).

Another example of naturally occurring demonstrated effects of electromagnetic pulse is seen in the 2003 northeast blackout affecting Ohio, New York, Maryland, Pennsylvania, Michigan, and parts of Canada. The blackout shutdown more than 200 power plants, some nuclear, due to the disconnection of electricity. On the first day of the blackout massive traffic jams and interstate gridlock brought highway transport to a halt. Traffic lights did not function resulting in delayed operator decisions and or traffic accidents. Second and third order affects arose when railways, gas stations, and oil refineries shut down. Parts of the U.S. motor vehicle and automotive parts industry were

shutdown inherently idling 100,000 factory workers. The U.S. steel industry experienced significant setbacks when explosions caused by the lack of power occurred in a blast furnace in Lorain, Ohio. This rendered a major component of the steel industry useless. In addition, radio and television stations were taken off air leaving the public to their own interpretation of the unfolding events (The Electricity Consumers Resource Council 2004, 1, 3, 6).

Earth is located 93 million miles from the sun, while that literally seems like light years away it is not far enough to avoid the EMP producing effects of a solar flare. Solar storms come around every 11 years in various intensity cycles emitting an electrically charged plasma packet into space, occasionally in the direction of earth. This electrical radiation affects the geomagnetic field of the earth. The emitted charge is representative of E1, and E2 electromagnetic pulses, which damages electrical devices. The intensity of this radiation in the form of a pulse can create a shocking effect that destroys connected electrically conductive materials within seconds (Cogan 2011, 1, 2).

Conventional employment of an EMP requires three components; a nuclear warhead, rocket or booster capable of reaching the upper atmosphere, and the intellectual knowledge of when to detonate versus distance in relation to the proportion of effect required to achieve a given end state. The U.S. conducted a conventional nuclear test at altitude during Operation Starfish Prime resulting in EMP like symptoms in the Hawaiian Island chain in the Pacific. The Soviets also conducted exo-atmospheric nuclear testing in the early 1990s through their testing programs. Their testing detonated a series of nuclear devices in the upper atmosphere above South Central Asia. Russian researchers directly observed damage to buried cables reaching as far as 600 km along the cable line. They

also observed transistor burnout, blown fuses, and power supply damage. Soviet testing is crucial to the realization that exo-atmospheric nuclear testing did not reside in the U.S. alone (Graham 2008, 2, 3).

The Commission to Assess the Threat to the United States from Electromagnetic Pulse Attack, reported that an EMP is capable of causing catastrophic consequences for the nation, and that the current vulnerability of our critical infrastructures, which depends so heavily on computers and electronics, can both invite and reward conventional attack (Electromagnetic Pulse Commission 2008, 2). According to a CRS report to congress in 2006 titled *High Altitude Electromagnetic Pulse and High Power Microwave Devices: Threat Assessments* adversaries such as China or Russia are capable of launching a conventional EMP strike against the U.S. Other nations such as North Korea could possess the capability as early as 2015 (Sirak 2004, 1). Additional nations that could produce an EMP within the next few years are the United Kingdom, France, India, Israel, and Pakistan.

Iran in 2005 supposedly acquired medium and intermediate-range ballistic missiles from North Korea with a range of 2,500 miles (Ben-David 2005, 1). In addition Iran tested several of their Shahab-3 ballistic missiles, which detonated in mid-flight. The world viewed these explosions as the result of a failed test by an incapable nation, however Iran stated the tests were fully successful. A member of the Senate Committee on the Judiciary, the Subcommittee on Terrorism, Technology, and Homeland Security stated that Iran's appearance of failed testing could be Iran disguising the practice of executing a successful HEMP detonation (Wilson 2008, 11).

Conventional employment is real however less likely to happen as overt measures of this affect could warrant an employing country unwanted worldly attention. It provides an overt indirect non-lethal strike capability for an employing country. The capability also ensures complete neutralization of electronics, which could potentially cause fatalities as a second or third order effect of an EMP. A country with the wisdom, tools, and disregard for worldly opinion could overtly and conventionally launch a ballistic missile tipped with a nuclear warhead into the atmosphere and detonate it creating widespread panic, fear, and disorder.

In a world with nuclear proliferation, a crude, covert, unconventionally employed nuclear weapon is far more likely than conventional nuclear employment. Third-rate countries or radical organizations striving to remain relevant and or exert their will may not want the worldly attention which conventional employment brings. For them executing an attack without a fingerprint could be seen as a better choice. An EMP is a phenomenal asymmetric weapon. An adversary would need a crude nuclear bomb, a Scud missile launcher purchased for around \$100,000, and the ability to move it on a freighter to the U.S. coast line in international waters. Once the missile is fired the vessel is scuttled removing the evidence, while effectively wiping away a fingerprint from the crime scene (Kramer 2009, 2).

Producing nuclear weapons grade material is still an extensive process, but with organizations like the Dr. Khan created Pakistani “Khan network” attempting to proliferate nuclear grade material for monetary profit one cannot discount a demand for nuclear materials on a “nuclear black-market” (Riddle 2004, 8). Due to the wide area effect of an EMP, precise accuracy is not necessarily needed therefore rough launching

measures could suffice. A short, medium, or intermediate range ballistic missile meeting payload capacity is suitable to deliver a nuclear warhead into the upper atmosphere. These smaller delivery systems are more attainable by smaller countries and or groups with big ambitions (Riddle 2004, 9).

### Highway Transportation

The United States of America has well over 4 million miles of roadway travelled by some 253 million registered vehicles. Highway transportation moves everything from your family to two million tons of hazardous material annually (Research and Innovative Technology Administration 2013, 33). The average miles driven a year per vehicle is around 12,000. The nation's freight also heavily relies on highway transportation as a way to move 622 billion dollars in freight each year (Transportation Research Board of the National Academies 2010, 3). With these statistics in mind it is safe to say highway transportation is a critical component to the way we live our lives.

The public depends on the vital economic functions of highway transport, as consumers and employees. The vast majority of these vehicles contain electronic systems which help navigate the highways with ease. Most vehicles on the road today have driver assistance and safety systems built in to monitor road traffic around the vehicle and or inform them of alerts. On board micro-processors run everything essentially under the hood to include; parking aids, electronic fuel injection (EFI), satellite navigation, cruise control, tire pressure monitoring systems, anti-locking brake systems (ABS), and engine management to name a few (The Royal Society for the Prevention of Accidents 2013, 2).

According to Oak Ridge National Laboratory's "2012 Vehicle Technologies Market Report," the top five tier one vehicle parts suppliers are located overseas. Johnson

Controls Inc. is the first tier one domestic parts supplier to make the list with only 37 percent of its product staying in North America (Oak Ridge National Laboratory 2012, 78). These tier one manufactures make replaceable parts, which include electronic parts for vehicles under their umbrella. While replaceable parts, safety features, and satellite navigation are components of Highway transportation they are not primary components. Highway transportation relies on two primary components which are the prime movers and road infrastructure. Research will specifically highlight electrical components of both subsets in order to facilitate understanding of an EMPs effect.

The term prime mover refers to a machine that transforms energy to mechanical form. In this case prime movers refers to automobiles, buses, and semi-trucks. The common thread between all prime movers is the ability to turn energy, be it electrical or combustion into mechanical form. Most prime movers on the road today have one of three types of engines which are, electrical, gas, and diesel. Prime movers use a spark from a spark plug to ignite combusted fuel. Spark plugs receive an electrical charge from wires which flow back to a distributor in older cars or an electronically controlled distribution box in modern vehicles. This electronically charged distribution box receives its spark from the starter, which draws power when the operator of the turns the key effectively connecting the on board battery to the electrical system. Most cars on the road today have electronic ignition modules which are essentially made up of a microchip. Fuel is delivered into the combustion engine by way of a microchip controlled fuel injector, most post 1985 model vehicles operate on electronic fuel injection (George 2012, 1). Engines are the most important component of a prime mover and effectively



create the mechanical power to move. At the heart of a prime mover electrical transactions make movement possible through wires and microchips.

Prime movers also have a dizzying array of onboard electronics to control everything from intake pressure to the common radio. Simple automobiles today may have as many as 50 microprocessors controlling various aspects of the automobile. Sophisticated engine controls are the job of the Electronic Control Unit (ECU) which processes a majority of transactions to adhere to stricter emission controls, regulate air and fuel ratios, and track coolant temperatures to name a few. This onboard computer performs millions of calculations every second a vehicle is operated to provide a cleaner and more efficient transit (Nice 2001, 2).

Modern prime movers use a multiplexing technique which simplifies wiring throughout the car. Multiplexing is necessary to reduce the amount of wire running through the prime mover. To multiplex the tradeoff of less wiring is the addition of a module with a microprocessor. This microprocessor receives inputs and outputs throughout the car and redirects the proper action for the directed inputs. For instance power mirrors, windows, and locks are all run off the same connected module (Nice 2001, 7). While technological advances make a more comfortable and efficient driving experience for the operator it also developed an electronically dependent system totally reliant upon electronic technology.

Over the past century the U.S. road infrastructure developed parallel to that of the economy. This mutually benefiting effect also led to a high dependence on road infrastructure to support the economy transiting it. Distances across America have shortened, making rural areas easier to access, while also allowing rural areas access to

more urban environments. Almost everyone in modern society depends on road infrastructure to buy groceries, go to work, and receive medical care. Society as a whole is totally dependent on roads in relation to the level of life style they wish to enjoy. To most roads are merely asphalt packed into the ground and level, however modern roads are much more than this. They are technologically advanced and electronically controlled (Electromagnetic Pulse Commission 2008, 128). The American Society of Civil Engineers (ASCE) issued a grade of “D” for America’s road infrastructure citing high congestion in urban areas wasting fuel and time. The cost from these inefficiencies is upwards of \$101 billion dollars annually. The Federal Highway Administration estimates a \$170 billion investment is needed annually to show significant improvement in the U.S. highway system (American Society of Civil Engineers 2013c, 1).

Modern roadways use traffic lights to control the flow of traffic in a safe manner. These traffic lights use to be mechanical in the early 1930’s, however modern traffic lights are much more than their 1930 counterparts. Traffic lights are now computer controlled, with many microprocessors, and often interconnected through electric wires to a main traffic control center for increased control by a higher authority. These manned control centers can effectively press a button and turn lights red or green depending on a given situation to control the flow of traffic. The synchronizing of traffic lights is a complex operation handled by a computer called a “master box” that records disruptions re-calculates synchronization. The communication between these master boxes, and control centers is only possible through the use of electrical devices such as a computer or wireless electrical connections. A traffic controller can use electronic surveillance cameras to monitor roadways, tunnels, and bridges to help them understand traffic

conditions so they can appropriately react (DeMarco 2010, 1, 2). Highway infrastructure continues to pursue the rapidly accelerating economy, while increasingly becoming more and more dependent each day on electricity.

### Rail transportation

Rail transportation in the U.S. is far from gone with line haul rail companies operating a \$433 million revenue. There are over 24,000 locomotives in service with well over 380,000 freight cars in service, moving 28 million carloads of freight each year. These freight and passenger trains navigate a vast railway system generating more revenue, per ton, per mile than highway based freight trucks (Association of American Railroads 2013, 1-3). Railroads transport 43 percent of the nation's intercity freight and around one third of U.S. exports. As the economy grows the demand on rail transport grows creating increased congestion on the rail network. As freight volumes increase the contributing congestion is costing the U.S. economy around \$200 billion each year in inefficiencies. Investment in the U.S. railway infrastructure is not enough to meet demand of supply. In 2012 alone, Amtrak a leading rail company moved over 31.2 million passengers across the country (American Society for Civil Engineers 2013, 2). Rail transport is far from extinct and maintaining adequate track capacity to address expanding freight and passenger needs is a significant challenge for the U.S. rail network.

Rail transport revolves around electrical technology to generate smarter more efficient railways. When you think of a rail road in relation to the "Wild West" it may help you remember a railroad consists of; two metal rails, wood ties, ballast, and metal nails. While this is the composition of the track railcars operate on, the rail networks are comprised of many electrically charged enablers. Railroads have signals, crossings, and

transformers. They are also command and controlled by interlocks, and electrical switches to change tracks or redirect rail cars (Railway Technology Development 2013, 1).

Railway locomotives or “Engines” are similar to highway vehicles in that they both have combustible engines, and both have a vast array of electronics to power them. Locomotives have electrical lines running throughout the engine and subsequent cars to power air conditioners, lights, and kitchen facilities. All locomotives operate on nominal 64 volt electrical systems connected to a battery by way of an electronic distribution control box. Similar to ABS on highway based vehicles, locomotives use an electronically controlled Dynamic Braking System which uses an electrical current to apply torque. Locomotives are chalked full of circuit breakers, radios, and electronic display screens (Nice 2001, 1).

Advances to modern day locomotives have morphed the engine room into a labyrinth of switches, gauges, and panels filled with electrically charged indicators. Like the automobile, the engine on a locomotive is electronically controlled by a microprocessor module. For passengers, longer distance trains are equipped with a kitchen ready to charge your credit card via an on board electronically charged point of sale system. Some trains operate strictly on electricity requiring massive microchip controlled transformers to distribute power. These electrically driven trains require two contact points a ground and a positive wire, in some cases a third track. Occasionally in cities positive wires run above the tracks for the length of the entire electrically driven railway (Freudenrich 2008, 3). In 2012, according to the *Class I Railroad Statistics* from the Association of American Railroads, U.S. railway prime movers moved 721,000 tons

of coal totaling 41 percent of railway transport dedicated to coal (Association of American Railroads 2013, 1). Coal continues to provide power to the U.S. through 2013, even with other sources of power utilized. Rail prime movers, like road prime movers, demand electricity to operate their combustion engines. Railway prime movers will not move if their electrical systems, which they solely rely on fail.

The American Society of Civil Engineers (ASCE) produced a report card on America's rail infrastructure for 2013 and they gave the U.S. rail infrastructure an overall grade of a "C+". According to the ASCE, rail transportation is experiencing a resurgence as society within the U.S. views rail a more energy efficient and environmentally friendly way to transport people and goods. Amtrak, a leading U.S. railway company, doubled its number of passengers since 2000 projecting continued growth into the near future. Freight and passenger rail continue to invest heavily in their infrastructure an example of this was the replacement of 3,100 miles of track replaced in 2010 from the Atlantic coast to the Pacific (American Society of Civil Engineers 2013b, 1). Railway transport is far from dead, and infrastructure development, while needing improvement is relied upon as a critical component to the U.S. economy.

Rail road tracks, which locomotives travel on are made of non-electric simple materials. The simplicity of railroad tracks disguises a vastly complicated electrically focused rail road infrastructure. Railroad tracks have electrically operated switches which change the direction of the travel on the given track. Most modern switches are operated by an electronic motor which takes commands from a remote controlled device (Freudenrich 2008, 6). Safety advances in railroad track geometry pairs with train cars and uses electronic and optical equipment to inspect track alignment, gauge, and

curvature. In addition for increased safety an onboard computer system in the locomotive analyzes track geometry on the move predicting the response of the train's freight cars in order to determine deviations and in certain cases notify the conductor of a problem. Railway bridges are outfitted with electronically operated remote monitoring devices which communicate to a control center on the structural health of a monitored bridge. The Rail Safety Improvement Act of 2008 mandated the use of Positive Train Control (PTC) on all rail main lines.

The railroads invested heavily in their tracks, bridges, and tunnels in the last decade, as well adding new capacity. Intercity and commuter passenger ridership are showing positive growth as a viable commuting option for urban areas. U.S. railways will continue to have higher demands than capacity to meet needs into the future clearly showing a heavy reliance on U.S. rail transport.

#### Supervisory Control and Data Acquisition systems

SCADA systems connect the world in a way which few physically see, but feel the effects. These automated systems do the work of humans by making decisions based on programming logic known as Programmable Logic Controllers (PLC). PLCs control actuators through pre-programmed commands and monitor sensors. Programmable Logic Controllers paired with Digital Control Systems (DCS) make up SCADA based systems, which act on a set of programmed orders or based on programming logic. SCADA systems enable a vast amount of transactions, actions, and information flow and are integral component of our society. The boom of the computer age boosted the use of these devices, and the inherent reliance upon them. SCADA systems grew with the technology they support, in parallel. The nation's critical infrastructure is reliant upon

SCADA systems to make billions of decisions in fractions of seconds every day. These automated machines increase economic benefit by doing the work of physical people, making pre-programmed decisions for given scenarios, and by providing a highly reliant level of operational agility (Electromagnetic Pulse Commission 2008, 1).

SCADA systems provide infrastructure application through electrical transmissions and physical distribution controllers. SCADA systems are in execution across the globe managing water supply, oil pipelines, and gas pipelines to name a few. SCADA systems originated in the in the railroad and aviation fields, and since has evolved with technological demand.

All SCADA systems do not look alike and differ by application. To a certain degree they share commonalities and physically resemble the internal components of a desktop computer. They contain circuit boards, micro-processing chips, and cable connections like a Local Area Network (LAN) cable. Cable are connected either by wire or wirelessly to sensors which act as the peripheral sensors of SCADA devices. Electronic control devices act on pre-programmed logic in relation to the data provided by its sensors to issue commands that adjust system performance (Electromagnetic Pulse Commission 2008, 2).

SCADA systems control various industrial systems and are at the core of many modern industries to include; manufacturing, energy, water, power, and transportation to name a few. SCADA systems are comprised of many sub-systems like programmable logic controllers, and digital control systems. Through its use of these sub-systems, SCADA systems monitor, process, and collect data. According to pre-programmed logic they analyze the data and issue highly efficient commands to actuators, regulating the

flow or direction of a given resource. SCADA systems are used globally, and are found at supermarkets, refineries, water treatment plants, and even in the common household (Inductive Automation 2014, 1).

These systems control critical U.S. infrastructure which is vastly interconnected and mutually dependent on other systems. According to the National Institute of Standards and Technology's *Guide to Industrial Control Systems Security*, private operators under federal regulations own around 90 percent of the nation's critical industrial infrastructure. Many federal agencies operate industrial processes like air traffic control, postal handling, and manufacturing capabilities which use SCADA systems. SCADA systems provide centralized monitoring and control through wired or remote means. Their commands regulate actuators, open and close valves, switch on and off breakers, and collect data from sensor systems while monitoring the local environment for logical alarm conditions (Stouffer 2011, 14, 15).

SCADA systems are a type of control under a general term called, Industrial Control Systems (ICS). SCADA systems are made up of interconnected sub-systems called Digital Control Systems and Programmable Logic Controllers. DCS are used to control processes like electrical power generation, oil refineries, and auto production. DCS systems contain the supervisory level control and oversee multiple, integrated sub-systems which are responsible for controlling localized processes. To control product and processes, Programmable Logic Controllers are integrated into the SCADA based systems. These PLCs are tuned through a Human Machine Interface (HMI) to a desired setting, as well as self-correcting processes. PLCs and DCS systems are computer based solid-state devices which resemble the internal components of a desktop computer. These



systems use electrical power, and possess microprocessors to execute programming. SCADA devices are used extensively throughout industry, and are highly efficient. SCADA devices can account for various automated workplaces. For example automotive plants employ SCADA devices to control their automated assembly lines. These automated devices replaced the need for physical human labor, increasing revenue and reliable accuracy (Stouffer 2011, 15).

Critical U.S. infrastructure is often referred to as a “system of systems” due to the sheer amount of interdependent systems which are mutually connected. These system of systems can cause a cascading failure if even one is taken off line. The loss of one single sub component of a system could cause an uncorrectable imbalance sending the entire system into cascading failure (Stouffer 2011, 27).

A prime example of the cascading effect of a SCADA failure was seen in November of 1999 in San Diego county. The San Diego Water Authority and San Diego Gas and Electric companies experienced a severe electromagnetic interference that disrupted their SCADA wireless networks. Each company was unable to actuate, regulate, or control their remote controlled valve sub-systems. This left critical valves open, and closed, requiring human technicians to physically deploy to valve locations to open and shut them as directed by their control center. If they were not successful in a manual override of the valves, the San Diego county aqueduct system would have “catastrophically failed”, according to the San Diego Water Authority in a letter to the Federal Communications Commission.

This failure had the potential to spill thousands of gallons of sewage a minute with the worst case being the complete rupture of 825 million gallons of raw sewage

flooding across southern California damaging the health, property, and creating a bio-hazardous situation for millions of Californians. The source of the SCADA failure was traced to electromagnetic pulses emitting from a radar system operated on a Navy vessel 25 miles off the coast of San Diego (Electromagnetic Pulse Commission 2008, 2).

While SCADA systems possess an automated outlet for efficiencies they also are a huge vulnerability with potential severe liabilities. As a system of systems one failure can lead to a cascading effect of failures. This cascading effect can reach across the nation in some form or fashion. The nation's essential service dependence on these electrically charged computer based systems creates a critical vulnerability of which could catastrophically affect the population. U.S. cyber defense measures were implemented to mitigate damage through the cyber spectrum from hackers, however physical defense of SCADA systems only prevents normalized weather effects, and not that of a natural or man-made EMP.

SCADA systems are a form of transportation and distribution, which as a nation, we critically rely upon to provide essential services to the public. These remotely automated systems are electronically executed through the cyber spectrum, and susceptible to physical attack. These systems provide a new vector of vulnerability in an ever evolving digital age.

### Kansas City Transportation

Kansas City's infancy began facilitating transportation along the Missouri river in the 1800s for French fur traders. It was the first city selected to receive interstate highways, thanks in part to a native of Abilene, Kansas president Dwight Eisenhower. Kansas City maintains all modes of transportation to include; highway, rail, inland

waterway, air, and pipeline. Due in large part to its geographic location, Kansas City is seen as a viable throughput location for trans-continental transport operations (Trunick 2007, 1). The city has one of the largest rail hubs in North America with 225 miles of rail within its limits. Within the city limits 197 miles of road include several interstates, highways, and local roads. The industrial sector of Kansas City is the largest user of mass ground transport as it produces millions of dollars in goods each year and uses four main distribution complexes to send them by way of all bulk transport means.

Pipeline transport is also significant in and around Kansas City, with the closest nuclear powered plant 65 miles away in Wolf Creek. Numerous power plants reside in and around the city, with hundreds of miles of pipeline carrying varying resources to the city and through the city. Two of the vital resources pushed through the pipes is natural gas, and crude oil. Also three hazardous material lines run around the city (U.S. Energy Information Administration 2014b, 1).

Kansas City has numerous SCADA devices helping to control its road, rail, and pipeline operations. These systems maintain intelligence at the expense of electricity to keep transport systems operating at maximum efficiency. Kansas City proper to include the Missouri and Kansas cities, geographically sits at the nation's crossroads connecting the Atlantic to the Pacific. It is a premier surface transport node for the U.S. connecting commercial trucking to commercial railways, while interchanging many people across the vast interstate highways. The main means of transport in and around Kansas City is by automobile, which the average commuter spends in upward of an hour each day to get to and from work. Those citizens not traveling by automobile account for around ten thousand, and travel by public bus transportation. The citizens of Kansas City firmly rely

on ground transport to support their lifestyles, while providing for their most basic life sustaining needs.

### Case Study: Operation Starfish Prime

In late 1958 the USSR re-initiated its high altitude nuclear testing causing the US to respond with tests of its own. The US was afraid that a Soviet nuclear bomb detonated in space could effectively damage affected satellites. In response President Kennedy signed off on Operation Dominic in 1962, that included 36 tests, of which 29 were delivered by airdrop and seven delivered by Polaris submarine launched ballistic missiles. A sub-operational set of Operation Dominic was a series of high altitude nuclear tests known as Operation Fishbowl, with one specific operation named Starfish Prime (The Nuclear Weapon Archive 2005, 1).

Starfish Prime launched a THOR missile with test instrumentation and a W-49 warhead/Mk-4 RV 1.4 Megaton payload 248 miles into the upper atmosphere above Johnston Island, an atoll 900 miles southwest from Hawaii (The Nuclear Weapon Archive 2005, 1). At 0900 UTC the nuclear warhead detonated in a spherical fashion, causing a shockwave in 360 degrees. The immediate effect of the blast was an aurora seen for a thousand miles around. The charged atom particles formed this aurora when falling back into the earth's atmosphere. Airplanes captured images of these charged atom particles, with their aurora effect as they fell back to earth (Plait 2012, 1).

During Operation Starfish Prime it was noted that a magnetic field was caused as a result of accelerated charged particles. This magnetic field disrupted electric currents in Hawaii, blowing out street lights, and causing telephone outages. It also caused electrical surges on aircraft in the area and created radio station disruptions. Also of note Starfish

Prime effected, as predicted by the US, satellites in space. It electrically damaged five satellites and one Soviet satellite, all of which failed due to the blast (Plait 2012, 1). The island of Oahu experienced surging power lines, blown fuses, destroyed transformers, blown circuit breakers, and triggered burglar alarms (The Nuclear Weapon Archive 2005, 1). Starfish Prime as part of Dominic was declared a success in proving to a degree the effects of a nuclear device detonated at high altitude (Plait 2012, 1).

#### Case Study: 1977 New York City Blackout

On 13 July 1977 naturally occurring lightning struck two critical power transmission lines at 8:30 p.m., which carried power from the Indian Point nuclear power generating station to New York City and New England proper. At 8:45 p.m. another lightning strike knocked out all but one power transmission lines, which supplied and transported power to upstate New York and New England power grids. In addition, also at 8:45 lightening destroyed two main feeder lines which serviced Westchester with power. Con Edison, the power company responsible for providing power began reducing voltage on the grid in response to the disruptions. At 9:20 another lightning strike knocked out the remaining transmission line north of New York City, effectively cutting off all power coming from the Indian Point nuclear reactor to New York City (Newsweek 1977, 26).

In response to the power drain created by the strikes, various circuit breakers automatically tripped at Long Island Lighting Co. to keep the drain from spreading across the grid to the south. While this action prevented damage to substations and generating stations it also rendered Long Island without power. Additional power grid transmission connections provided by Con Edison to Pennsylvania, New Jersey, and Maryland

overloaded as a result of the lightning strikes and automatically shut down, leaving those states with less power as a result. The New York City Ravenswood generating station automatically shut down at 9:30 to protect itself from overloading and resulted in total burnout. This last action at Ravenswood rendered New York City proper, completely powerless and in a state of blackout (Newsweek 1977, 27).

The power outage in New York City lasted for 25 hours and facilitated mass looting and chaos across the city. Looters saw the blackout as a huge opportunity to get what they wanted amid the chaos of the moment. An estimated 2,000 places of business were looted as a result totaling an estimated one billion or more in property loss. The human toll was also of note as hundreds of people were hospitalized, 44 firefighters were injured battling hundreds of fires across the city. The police made a valiant attempt at restoring order, but were quickly overwhelmed after detaining 3,776 persons conducting criminal activity during the 25 hour blackout. The police shifted their focus to containing the looters rather than arresting them, as the burden was too great (Newsweek 1977, 18).

During the 25 hour blackout, nothing electrically worked except telephones, and transistor radios. The New York subways stopped and left 1,000 plus passengers stranded along lines across the city. A city known for its epic high rise buildings also saw many trapped in powered elevators, dangling powerless in the shaft. Water pumps across the city failed, leading to personal hygiene and potable water shortfalls across the population. Since this event occurred in the dead of summer, refrigeration units and air coolers stopped working leaving many to open their windows and doors to cool their residences, if of course they could fend off the looters (Newsweek 1977, 21).

It took Con Edison over four hours to restore initial power to 150,000 citizens as they attempted to fix numerous underground cable networks in order to get the other 2.8 million customers power. After 25 hours in the dark New York citizens regained electrical power, and looked toward figuring out exactly what went wrong, so they could avoid another dark future (Newsweek 1977, 22).

#### Case Study: 2003 North East Blackout

On 14 August 2003 at 4:00 P.M. a cascading blackout occurred across the north east of America and south east of Canada. The power went out in portions of; Ohio, Michigan, Pennsylvania, Massachusetts, New York, Connecticut, New Jersey, and Ottawa, Canada. The power outage caused numerous airports, trains, subways, tunnels, and airports to shut down. Hospitals had to resort to using their backup generators for power, while cell phone towers, cash registers, ATMs, and point of sale machines remained powered down. Specifically, in New York City, commuters were stranded and were forced to walk home, because ground based public transportation was halted. Elevators, air conditioning units, and water pumps remained halted due to a lack of power (George Mason University 2014, 3).

Considering the fresh events of 11 September 2001, some citizens of New York thought they and the nation may even be under attack, again. In, Cleveland water, electric pumps shut down and deprived 1.5 million customers of potable water throughout the city. In addition to the inoperable water pumps, stores began price gouging essential supplies like bottled water, and batteries across the city (George Mason University 2014, 4).

There are a few theories as to how this failure started, and it can be determined that the sheer size of the area affected was caused by a cascading failure. It is not known if an electromagnetically charged lightning strike occurred somewhere along the grid in Ohio due to the fact that the energy company responsible failed to maintain situation awareness and understanding of their network. The U.S.-Canada Power System Outage Task Force conducted the final report on the blackout to both the U.S. President and Canadian Prime Minister. In their report, one critical cause or root failure could not be determined due to the lack of understanding First Energy, the company responsible for the power grid in Ohio, had over their area of responsibility. The Task Force noted on 14, August 2003 a series of failures and glitches occurred at two Independent System Operators (ISO). These operators oversee electrical power utilities and transmission lines. As failures and glitches mounted, throughout the afternoon, regional transmission lines tripped and power plants automatically shut down to preserve themselves from overloading. In addition a set of high voltage power lines interacted with overgrown tree branches and shut down the entire high voltage line (U.S.-Canada Power System Outage Task Force 2004, 17, 45). The pinnacle of the failures came at around 4:00 P.M. when a series of cascading interactions among the physical grid, the computers monitoring, and human operators resulted in a massive cascade of failures. By 4:25, the cascading power failures had shut down eight states, and one from Canada. The resulting effect left 50 million people in the dark across 9,600 square miles (George Mason University 2014, 10).

It took around 30 hours to restore power to New York City, and upwards of four days in some outlying areas. The overall economic impact of the blackout was estimated



to be around four to six billion dollars to include Ottawa, Canada. As for New York City, it learned from the blackout of 1977 and averted mass looting due to its increased security presence. However, the U.S.-Canada Task Force noted striking similarities to earlier historical blackouts, and that efforts to implement earlier recommendations and lessons learned were not adequate (U.S.-Canada Power System Outage Task Force 2004, 139). Ultimately, six months later, the U.S.-Canada Power System Outage Task Force found that a combination of human error and equipment failures had caused the blackout. They specifically identified the failure of an alarm processor in the control system of ISO First Energy. This alarm failure prevented their control room from having a proper situational understanding of critical operational changes to the electrical grid. The failed alarm could not detect several key transmission line failures in northern Ohio when and if they came in contact with trees. This initiated a cascading failure of 508 generating units at 265 power plants across eight states and Canada. The task force also specifically noted the dysfunction of numerous SCADA devices connected to the power grid, which also contributed to the cascading effect (George Mason University 2014, 11, 12). The blackout of 2003 is a premier example of cascading failures, and the magnitude they can have over time.

### Assessing Disaster Magnitude

To understand fully the effect of an EMP on transport infrastructure a thorough review of literature into the assessment of disaster magnitude on a scale, will provide perspective and social context. Within the assessment a review of social behavior during a disaster will provide perspective for bridging correlations among physical transport, SCADA, and an EMP event. Assessing on a scale, the impact of a disaster event on a

society, in relation to their reaction will provide situational awareness while illustrating the human effect during an EMP strike. While conducting a review of literature into the assessment of disaster magnitude the researcher found a minimal literature which coherently and collectively agrees on a base definition to assess an event's magnitude. The pure definition of “disaster” is disputed by many organizations and scholars around the world.

Disasters generally are defined in three specific research areas, the classic approach, hazards-disaster tradition, and the social phenomenon tradition (Perry 2006, 1-15). The classic approach generally characterizes disasters as an unplanned disruption that impacts a community. In 1961, Fritz proposed a definition of a disaster as “an event, concentrated in time and space, in which society undergoes severe danger and incurs losses to its members and physical appurtenances.” (Fritz 1961, 651, 652). The hazards-disaster tradition narrowed the focus on the interface between the physical or built environment and a social system. Due to the belief that social systems are the real source of vulnerability (Quarantelli 2005, 325-328). This thought emphasizes that disasters flow from the overlap of the physical, constructed, and social environments (Mileti 1995, 1). Finally, the social phenomenon theory focuses completely on the social environment. It emphasizes the impact to social systems, norms and resources as constituting a disaster.

Even within pre-defined “traditional” definitions they differ for instance, Tom Horlick-Jones argues that a range of factors of which fatalities are only one characterizes disasters. He argues that the “Bradford Disaster Scale” should instead be titled the “Bradford Fatality Scale” due to its reliance on defining disaster by the number of

fatalities reported. Horlick-Jones did not find fatalities a necessary condition for an event to be perceived as a disaster (Horlick-Jones 1995, 146, 147).

As with disjointed or differing perspectives on the definition, organizations struggle to cohesively define disaster. The United Nations defines disaster as a “Serious disruption of the functioning of society, causing widespread human, material, or environmental losses which exceed the ability of the affected society to cope using only its own resources”. While the Federal Emergency Management Agency (FEMA) defines disaster as, “An occurrence that has resulted in property damage, deaths, and or injuries to a community”. Through these two definitions we see conflicting definitions of disaster as FEMA’s definition states “any” loss, whereas the U.N. defines it as any loss above what the affected society can handle. Here is a hypothetical example to illustrate the point, say a train derails and injures 15 people, that event could be defined as an overwhelming disaster for a smaller city or county, but easily handled by a larger city or county with greater access to resources and classified by them as a minor inconvenient accident.

The researcher found and focused in on two specific articles, both of which discuss the impact of disasters on society through qualitative and quantitative analysis. The first article written by Harold D. Foster titled, “Assessing Disaster Magnitude: A Social Science Approach” attempts to define disaster magnitude using a number of sociological and psychological sources in a quantitative and qualitative combination. He defines disaster as a varying relationship between damage suffered and lives lost. With an ability to compare disasters on a global scale, a scale of disaster magnitude helps to provide a historical foundation of measurement. The problem Foster identifies to

establish disaster magnitude, is a defined common unit of measurement which can be used to broadly compare a facet of disaster. To combat this problem Foster looks to measure the societal coping behavior of the individuals affected. The resulting effect on their ability to cope is calculated into a “stress” factor (Foster 1976, 1).

Foster used, “The Social Readjustment Scale” from Thomas H. Holmes and Richard H. Rahe to define stress from a sociological and psychosomatic perspective. Holmes and Rahe developed a social readjustment scale by exploratory question testing of a sample population consisting of 394 people. Each subject was asked to rate a series of 43 events on a scale from 1 to 500. The events ranged from pregnancy and divorce to the death of a spouse or outstanding personal achievement. As a result of this testing they reported consistencies in relative order and identified clear patterns. This rating scale was used by Foster to assign “life stress” values to those events commonly occurring during a disaster (Holmes 1967, 213). Foster identified four variables when applied in a base formula defined total stress caused during a disaster. The four variables he used are; number of fatalities, the number of seriously injured, the infrastructural stress value associated with an event of a given intensity, and total population affected. Using these variables in relation to past historical events he generally defined event magnitude for past disasters and placed their quantitative magnitudes on a magnitude scale (Foster 1976, 244, 245).

Foster’s magnitude scale, and infrastructure stress values provide a general utility to define the amount of disaster an event created. Both Holmes and Rahe assist in defining societal and psychosomatic stress on an individual, which in concert with Foster helps provide social, psychological, and infrastructure context to a disastrous event.

Understanding the stress level and disaster level an EMP creates in society through physical and psychological means accounts for human elements which bridge the gap between man and the machines of the transport world, while providing a global context and scale on which to measure and compare to other disasters.

### Summary

Electromagnetic pulse is a real threat, and one which could greatly damage electrical devices beyond repair. An EMP is an extremely attractive, indirect weapon that will favor an employment of secrecy with catastrophic results. While the technology is steep, it is not out of reach for the right price. Nearly all automobiles and locomotives run off of advanced electrical technology in some form or fashion. The citizens of the U.S. and Kansas City specifically are dependent on the use of auto and rail transport to live their lives. As Kansas City resides at the nation's heart it too lies as one of the most critical transport and distribution hubs in the U.S., connecting all cardinal directions of travel. One EMP detonated above Kansas City could have lasting effects not only in the city, but also on a greater scale in the U.S., and possibly North America.

## CHAPTER 3

### RESEARCH METHODOLOGY

#### Purpose

The purpose of this research is to analyze three historical case studies and make general correlations among them to develop assertions, which will be applied to an analysis of Kansas City's transportation based systems. The result will produce conclusions, findings, and areas for further research. Chapter 3 contains the framework and methodology used to understand effects as they relate to the primary research question. The primary research question is: How will an Electromagnetic Pulse (EMP) strike targeting Kansas City affect its road and rail based transportation distribution infrastructure? This research will also address one secondary question: What are the second and third order effects if a city's surface transportation infrastructure is shut down? This chapter details the framework and research method used for analysis.

#### Framework

The researcher selected a qualitative, multi-case study approach to solving the problem due to the specific lack of unclassified research conducted on this topic. Using John W. Creswell's *Qualitative Inquiry and Research Design: Choosing among Five Approaches* as a guide, the framework of analysis of this research project is designed around a multiple case study method. Each case study will begin with an introduction detailing times, locations, and events as reported or documented from various sources. This will provide contextual detail through descriptive evidence for each case study. The introduction will also illustrate why the case study was selected, and its relation to the

broader topic of research. Each case study will outline the development of issues as they relate to three sub-topics; Impact to highway transport, impact to rail transport, and impact of SCADA systems. These categories will provide data analysis as a basis for making general assertions. Finally, each case study will close with assertions of presenting material in a broader scope, and analyzed against the other case studies for common themes (Creswell 2007, 73, 79).

### Method

The researcher used John W. Creswell's *Qualitative Inquiry and Research Design: Choosing among Five Approaches* as a basis for qualitative research with the multiple case study method selected. The three case studies used for this research method are: 1960s Operation Starfish Prime, the 1977 New York City Blackout, and the 2003 North East Blackout. These three case studies were used for a number of different reasons to illustrate common themes in natural, man-made, and non-EMP strikes. The Operation Starfish Prime case study is used as a man-made example of an EMP effect, and one of the earliest man-made examples available dating back to the 1960s. The second case study of the New York City Blackout of 1977 provides a natural EMP example, and provides a clearly documented perspective of society in 1977 as a result of the effect. It also shows how fast technology develops between decades, and the growing dependence on it. The final case study of the North East Blackout of 2003 illustrates a non-EMP strike with similar effects to the 1977 blackout. It magnifies the cascading failure effect of SCADA systems in relation to transportation systems when the power grid fails. It also spans two decades from 1977 and helps to show the speedy pace of technology in relation to energy dependence and helps to highlight a modern case study

of similar effect. All three case studies together bridge generational gaps in society, and generational gaps in technological advances. These three case studies will be used to make general assertions used in the developed Kansas City impact theory.

The fourth area analyzed in this chapter is Kansas City's transportation infrastructure. Detailing Kansas City's transportation infrastructure will allow for EMP assertion and application within its analysis. Kansas City will be analyzed across all transport categories with emphasis on electrical components vulnerable to an EMP strike. Using time and space, the researcher hopes to provide a stronger foundation of detail in an easily understandable fashion, in relation to societal context, and furthermore in relation to the problem itself.

The three case studies are analyzed through twenty-four criteria, which vary from "yes/no" responses to numerical values. Criteria are placed into five categories of; EMP, disaster magnitude, highway transport, rail transport, and SCADA systems. Criteria number six and seven will assist in placing events in social context and are analyzed against Harold D. Foster's "Infrastructural Stress Values" table in the article titled, "The Professional Geographer" published by Routledge in 2008. This article helps rationalize, categorically, a societies stress level in relation to a given event. Based on an events various characteristics, it is assigned a base line stress level number in accordance with Foster's Infrastructural Stress Value table. This quantifiable data is then given a designation based on the specific category of the event data. In essence, the characteristics of an events intensity on the population can be measured and will be used in this research study. Cross analysis will be conducted across case studies, but not across



criteria (Foster 1976, 241-244). Foster's Infrastructural Stress Values table is shown below.

### INFRASTRUCTURAL STRESS VALUES


Event Intensity	Designation	Characteristics	Stress Value
I	Very minor	Instrumental	0
II	Minor	Noticed only by sensitive people.	2
III	Significant	Noticed by most people including those indoors.	5
IV	Moderate	Everyone fully aware of event. Some inconvenience experienced, including transportation delays.	10
V	Rather pronounced	Widespread sorrow. Everyone greatly inconvenienced; normal routines disrupted. Minor damage to fittings and unstable objects. Some crop damage.	17
VI	Pronounced	Many people disturbed and some frightened. Minor damage to old or poorly constructed buildings. Transportation halted completely. Extensive crop damage.	25
VII	Very pronounced	Everyone disturbed; many frightened. Event remembered clearly for many years. Considerable damage to poorly built structures. Crops destroyed. High livestock losses. Most people suffer financial losses.	65
VIII	Destructive	Many injured. Some panic. Numerous normal buildings severely damaged. Heavy loss of livestock.	80
IX	Very destructive	Widespread initial disorganization. Area evacuated or left by refugees. Fatalities common. Routeways blocked. Agriculture adversely affected for many years.	100
X	Disastrous	Many fatalities. Masonry and frame structures collapse. Hazard-proofed buildings suffer considerable damage. Massive rebuilding necessary.	145
XI	Very disastrous	Major international media coverage. Worldwide appeals for aid. Majority of population killed or injured. Wide range of buildings destroyed. Agriculture may never be reestablished.	180
XII	Catastrophic	Future textbook example. All facilities completely destroyed; often little sign of wreckage. Surface elevation may be altered. Site often abandoned. Rare survivors become life-long curiosities.	200

Figure 3. Infrastructural Stress Values

Source: Harold D. Foster, "Assessing Disaster Magnitude: A Social Science Approach," *The Professional Geographer* 28, no. 3 (1976): 244.

Analysis is captured after each case study in the table below to provide a visual depiction after each case study, and will build upon each case study to show correlations and confirmations. The data points will assist in the formation of assertions and conclusion under the combined four categories of; EMP, Road transport, Rail transport, and SCADA system. This will allow application of focused assertions and conclusions against Kansas City's transport model. This visual depiction will provide the ability for quick reference analysis and provide a broader scope across all cases studies, and in overall relation to the Kansas City impact theory.

Table 1. Table of Analysis

Multiple Case Study Method		1960s Operation STARFISH PRIME	1977 New York City BLACKOUT	2003 North East BLACKOUT	Kansas City (Impact Theory)
Criteria of analysis by category					
EMP	Type of EMP displayed (Manmade/Natural/Undetermined)				
	EMP type of pulse displayed (1,2,3)				
	Approximate size of known area affected (Miles)				
	Electrical grid damaged (Y/N)				
	Time of residual effect				
*	Event stress level (0-200)				
	Event designation				
Highway Transport	Local transport disruption (Y/N)				
	Physical movement disrupted (Y/N)				
	Traffic control measures operational (Y/N)				
	Automobile/Trucks disabled (Y/N)				
	Traffic Operation Centers Disrupted (Y/N)				
Rail Transport	Traffic congestion impeding flow of transport (Y/N)				
	Number of highway vehicle accidents reported				
	Rail transport disruption (Y/N)				
	Rail Control Center disrupted (Y/N)				
	Rail traffic control measures operational (Y/N)				
SCADA Systems	Rail prime movers disabled (Y/N)				
	SCADA control systems damaged or disabled (Y/N)				
	Electrical transmission distribution disrupted (Y/N)				
	Sensor system disruption (Y/N)				
	Sensor system level of failure (PLC/RTU/ECU)				
	Pipeline distribution disrupted (Y/N)				
	Cascading SCADA system failure displayed (Y/N)				

\*

 Infrastructural Stress Value Data

\*

 Impact Theory applied in CH 5, Findings

Correlation within category
  Confirmation of effect

Source: Created by author with two integrated categories developed by Harold D. Foster, "Assessing Disaster Magnitude: A Social Science Approach," *The Professional Geographer* 28, no. 3 (1976): 244.

### Strengths and weaknesses of selected method

The qualitative case study provides strength to this topic through flexibility, data collection, and historical evidence in relation to a social context. While there are significant strengths, a few weaknesses exist to validity, reliability, and over generalization (Creswell 2007, 75-76). The topic of EMP is fairly small in scope of a history of application, and even smaller if you apply it to transportation. Due to the underdevelopment of this topic the researcher chose to look at case studies from different perspectives to mitigate a shortfall in validity by selecting one case of a man-made EMP strike, and two naturally occurring disasters which exhibited different pulse levels commonly found within an EMP effect. The researcher also identified these three case studies against three different generational gaps in order to mitigate a shortfall in the reliability of data due to a like technological time period affecting the formulation of applied theory.

The case study method assists the researcher by allowing for flexibility within a vague spectrum, while providing relevant historical data to qualitatively deduce conclusion and generalizations. A weakness of the case study method is over generalization. To mitigate this shortfall the researcher developed specific non-subjective criteria for analysis, which will maintain research integrity by preventing the researcher's bias from interfering with analysis and allow for critical scrutiny.

The qualitative approach will enable the study of the social phenomenon in an attempt to draw conclusions in relation to social context (Creswell 2007, 78-80). A shortfall exists in attempting to understand societal stress, and reaction. The researcher chose to use Harold Forster's approach to "Assessing Disaster Magnitude: A Social

Science Approach” in order to qualitatively quantify the social phenomenon to a disaster. The use of Foster’s research attempts to mitigate social irregularity and reinforce valid social and physical infrastructure conclusions.

### Summary

Using a qualitative approach, through a multi case study method the researcher aims to provide relevant, and valid results on a topic that is woefully under researched, in the researcher’s opinion. Results, data points, and correlations discovered in the three case studies will be applied to Kansas City. Under a normalized EMP scenario the researcher will develop a theory of how an EMP strike will affect Kansas City’s transportation, addressing the primary research question. As data and application points are developed the researcher strongly believes, to a degree, the secondary research question will be answered while conducting normal analysis into the primary question.

## CHAPTER 4

### ANALYSIS

#### Case Study: Operation Starfish Prime Introduction and EMP analysis

Operation Starfish Prime was a subordinate operation under Operation Fishbowl, and subsequently underneath the larger atomic testing operation called, Dominic. Operation Dominic was a series of atomic tests in the vicinity of Christmas and Johnston Islands in the central Pacific during 1962. Operation Dominic followed Operation Nougat, and was above ground unlike Nougat, which conducted restricted low-yield device testing underground. Operation Dominic included 36 above ground tests, with 29 airdrop deliveries, and the rest either launched by Polaris based submarines, or Thor missile delivery systems. Operation Fishbowl was specifically a series of five tests conducted at high altitude by Joint Task Force 8 or JTF-8 commanded by Major General A. D. Starbird (Narin, Ogle, and Dumas 1962, 9). The thermonuclear warheads were launched by Thor missiles to between 30-248 miles above ground to evaluate destructive mechanisms and effects of high yield explosions against ballistic missiles. Some of the tests failed with missiles being destroyed in flight and or on the launch pad. The initial Operation Starfish rocket motor malfunctioned and veered off course and out of control splashing down in the ocean. Operation Bluegill Prime, an operation under Fishbowl also electronically malfunctioned however on the launch pad, and was destroyed while still on the launch pad resulting in the complete reconstruction of the obliterated launch pad and plutonium contaminated Thor launch facility (The Nuclear Weapon Archive 2005, 1).

The second attempt to launch Starfish Prime, resulted in success on 9 July 1962. The Thor missile carried the plutonium charged Mark-4 RV/W-49 warhead, a direct descendant of the Mark-28 thermonuclear bomb, 248 miles above the earth's surface. The device detonated as intended and was felt more than 1,400 miles away at Kwajalein Atoll, and 800 miles away in Hawaii. The effects lit up the sky and created artificial auroras lasting around 7 minutes. Several government tests confirmed the presence of E1, E2, and E3 pulses emitted from the detonation (Narin, Ogle, and Dumas 1962, 13, 19, 21). These pulses were felt as far away as Hawaii at 880 miles. Surface and aircraft, experimental platforms were located throughout the Pacific basin, and some were directly underneath the blast on Johnston Island. Other experimental platforms were airborne and seaborne to assist in data collection. Specifically, the U.S. Air Force flew ten different types of aircraft ranging from U-2 high-altitude reconnaissance aircraft to lower-altitude WB-50 aircraft in support of JTF-8's mission. In total 21 aircraft were in the air during tests for Operation Starfish Prime, and collected results not available in the unclassified medium (U.S. Defense Nuclear Agency 1983, 213-223).

The electromagnetically charged aurora glow from the Starfish Prime shot lasted for hours. An interesting side effect was that the Royal New Zealand Air Force was aided in anti-submarine maneuvers by the light from the explosion. Land, airborne, and sea sensors reported strong electromagnetic signals at many hundreds of kilometers from the blast. Microbarograph signals from the detonation were observed at Johnston and Christmas Islands. Magnetic field disturbances were felt throughout the world to include both the North and South poles, according to the technical findings (Loadabrand and Dolphin 1962, 31).

Johnston Island and the Northern Hemisphere experienced a High Frequency black out for a short time, with moderate interference lasting for several hours. Even certain low frequency communications blacked out as far away as Melbourne, Australia. The strongest communication degradation to occur in the Australia, New Zealand, and Cook Island areas. Johnston Island itself was completely blacked out for the entire night following the detonation. At around five minutes after the blast the “Voice of America” American broadcast radio show in Hawaii, went down for sixty plus minutes (Hoerlin 1976, 20).

Operation Starfish Prime is one of a very few known man-made high-altitude thermonuclear tests, which caused electromagnetic effects that were actually captured. While to the eye the farthest location to see the effect was 1,600 miles away, the effect reached further than initially thought. The residual electro-magnetic effect lasted from seven minutes to four hours with radio stations and waves severely impacted. In one specific instance, electrical grid components were damaged on the Hawaiian Islands as a result of the electromagnetic effect. Damage to the electrical grid of Hawaii could have been more severe had solid state technology been fully implemented prior to 1962, as they were mainly still operating off of tube and transistor based technology.

To place Operation Starfish Prime in social context an assessment of the disaster magnitude in relation to Foster’s Infrastructural Stress Value is calculated in this case as, Moderate. Moderate being an event intensity level of four with characteristics representative of the immediate population’s awareness of the event, with some being inconvenienced, and the possibility of transportation delays. The stress value associated with this event is 10 on a scale of 1-200 (Foster 1976, 244-246). The immediately

impacted population's stress level did not appear to have affected the results and or the outcome of this test, nor did it create second or third order effect in relation to the transportation categories researched. The researcher believes the event stress for the actual Soldiers, Sailors, Airmen, and Civilians conducting the research to be a degree higher due to their inherent knowledge of the operation and to its possible but unconfirmed effects. Whereas the general population, like the civilians in Hawaii, understood it to be an extended Fourth of July celebration.

### Transportation Analysis

Since Operation Starfish Prime was conducted on a remote island chain in the central pacific the closest area of interest for research into highway transportation is the Hawaii island chain. During Operation Starfish Prime, numerous observers witnessed the detonation in a research capacity. In addition, local civilians also witnessed the detonation to a degree, in that they were prepared ahead of time and put together "A-bomb" parties. The Honolulu Advertiser, a local newspaper printed its headline to the detonation as, "N-Blast tonight may be dazzling; good view likely" (Smithsonian.com 2014, 1). During the night of Operation Starfish Prime no significant local ground transport disruption occurred within the Hawaiian Island chain. Physical movement was not disrupted or reported as a result of the detonation.

Traffic control measures were in fact disrupted with some 300 streetlights destroyed due to electromagnetic pulses travelling along the electrical wires, which disrupted and overpowered the electrical grid. Not only did the street lights fail, but so did a key transformer along the grid regulating the flow of energy. The outages of streetlights did not present any significant stoppage or disruption to transportation on



Oahu, however the test was conducted at 2300 local, and most citizens were probably enjoying a fresh cocktail at their self-designated “A-bomb” parties. Results from the outage were not reported as a disruption to the flow of transport as it was seen as an inconvenience (Hoerlin 1976, 31).

Due to the timeframe Operation Starfish Prime was executed in 1962, automobiles were for the most part mechanically driven. Electronic starters were working their way into designs and on the road in the 1930s, and were most likely the only major critical electrical component in an automobile at the time, which assisted in producing power for transport. Larger, more technical electronic devices such as Electronic Fuel Injection didn’t make their way into automobiles until after its invention in Britain in 1966 (Bellis 2014, 2). Therefore the researcher assumes that automobiles and trucks on the Hawaiian Islands were not directly disabled due to Starfish Prime’s detonation. The researcher also did not find any reports or data to suggest automobiles or trucks were disabled during the time frame of Starfish Prime. Observations and reports did not suggest any vehicular accidents as a result of the traffic light outage and or any other related cause to the operation. Minimal reporting or observations were found in the focus area of highway transportation in relation to the detonation.

Like the highway analysis in relation to Starfish Prime, the closest location with railway transport capability was the Hawaiian Island chain, specifically the Big Island and Oahu. Eyewitness accounts and reports from Starfish Prime do not suggest rail transport was disrupted in any capacity due to the detonation of Starfish Prime. As with automobiles in Hawaii during this time, locomotive engines were primarily mechanical in nature, operating off of coal and steam to propel them. In addition rail operations were

severely damaged in Hawaii due to the massive tsunami strike of 1946. The tsunami effectively knocked out rail operations on the Big Island by collapsing bridges, trusses, and some tunnels. This left Hawaiian rail operations in a state of repair and rebuild prior to the 1960s (Laupahoehoe Train Museum 2014, 1). Railways in Hawaii during the 1962 blast would not have felt the effect of a high-altitude thermonuclear detonation due to their lack of critical electrical components and infrastructure.

The first impact to a SCADA like system was seen above earth with several small satellites in low orbits at around 1,000 km above the earth's surface. The US-UK satellite named, Ariel was at a distance of 7400 km away from the detonation at Johnston Island. The detonation created artificial radiation in the Van Allen belts and four days following the detonation Ariel began operating intermittently due to a deterioration of its solar cells, in conjunction with on board SCADA power regulators failing to facilitate an effective battery recharge (Hoerlin 1976, 25).


In addition to Ariel, two other US satellites and a Russian satellite suffered a similar fate when their ability to transmit data was intermittent, and they eventually succumbed to a degradation of their ability to regulate power through SCADA devices. The final US satellite to receive damage to its electrical controlled SCADA systems was Injun I, Telstar. Telstar was launched one day after the Starfish Prime detonation, and was overcome months later by failures to its command and control module, and electronic circuit components. Telstar was a state of the art satellite at the time, and one would correlate the residual radiation of Starfish Prime in the Van Allen belts to its demise. The Los Alamos Scientific Laboratory Optical Station on top of Mount Haleakala on Maui Island received damage to an unprotected electrical regulatory

component of its system. Also of note a microwave repeating station on Kauai was damaged and unable to effectively transmit telephone signals (Vittitoe 1989, 1, 5, 8).

### Summary

Operation Starfish Prime is one of a very few partially unclassified man-made above ground high-altitude EMP case studies that can be researched on any level. It provides a study of the effects of a man-made EMP on the environment. While the analysis into transportation is relatively light it did provide confirming evidence that man-made EMPs, even back in the 1960s tube based transistor era would feel a EMPs effect. One could assert more electrical grid damage could have occurred to the electrical grid if tube technology was fully replaced with solid state technology prior to 1962. If Hawaii during the 1960s was representative of current technology the researcher believes strongly that the effects of the blast would be magnified. Looking at a combination of small occurrences like streetlights failing, an observatory damaged, and satellites unable to regain power are all indicators of a correlation between EMPs and electronics commonly found in support of transportation infrastructure. A summary of the analysis is depicted in the table below.

Table 2. Table of Analysis, 1960 Operation Starfish Prime

Multiple Case Study Method		1960s Operation STARFISH PRIME	1977 New York City BLACKOUT	2003 North East BLACKOUT	* Kansas City (Impact Theory)
Criteria of analysis by category					
EMP	Type of EMP displayed (Manmade/Natural/Undetermined)	MANMADE			
	EMP type of pulse displayed (1,2,3)	1,2,3			
	Approximate size of known area affected (Miles)	1,600 miles rad.			
	Electrical grid damaged (Y/N)	Yes			
	Time of residual effect	4hours			
*	Event stress level (0-200)	10			
	Event designation	Moderate			
Highway Transport	Local transport disruption (Y/N)	No			
	Physical movement disrupted (Y/N)	No			
	Traffic control measures operational (Y/N)	No			
	Automobile/Trucks disabled (Y/N)	No			
	Traffic Operation Centers Disrupted (Y/N)	N/A			
	Traffic congestion impeding flow of transport (Y/N)	No			
	Number of highway vehicle accidents reported	UNK			
Rail Transport	Rail transport disruption (Y/N)	No			
	Rail Control Center disrupted (Y/N)	No			
	Rail traffic control measures operational (Y/N)	UNK			
	Rail prime movers disabled (Y/N)	No			
SCADA Systems	SCADA control systems damaged or disabled (Y/N)	Yes			
	Electrical transmission distribution disrupted (Y/N)	Yes			
	Sensor system disruption (Y/N)	No			
	Sensor system level of failure (PLC/RTU/ECU)	N/A			
	Pipeline distribution disrupted (Y/N)	Yes			
	Cascading SCADA system failure displayed (Y/N)	Yes			

\* Infrastructural Stress Value Data
 \* Correlation within category
 \* Confirmation of effect

\* Impact Theory applied in CH 5, Findings

Source: Created by author with two integrated categories developed by Harold D. Foster, "Assessing Disaster Magnitude: A Social Science Approach," *The Professional Geographer* 28, no. 3 (1976): 244.

### Case Study: 1977 New York City Blackout

#### Introduction and EMP analysis

Amid the heat of midsummer the entirety of New York City and Westchester County lost power on 13 July 1977. Eight million people were without power across the metropolitan area with commercial and industrial services at a standstill for more than twenty-four hours. Although no life was lost as a direct result of the blackout, mass

looting and severe property damaged occurred. The collapse of the Con Edison power grid occurred from a number of natural events, equipment malfunctions, and operator error. At 8:37 P.M. on 13 July a severe thunderstorm occurred, creating lightening which struck two maximum capacity high voltage lines in northern Westchester County. This county laid at the farthest edge of Con Edison's northern grid boundary (U.S. Department of Energy 1978, 1).

The lightening that damaged Con Edison's lines was comprised of E2 and E3 naturally formed electromagnetic pulses commonly documented and found in lightening. The E2 pulses are able to damage and or destroy unprotected systems. In this case the Con Edison lines were a key vulnerability in relation to an E2 or E3 strike. The E2 pulse is a compounding pulse, which in this case carried itself a great geographic distance, across the grid. The E3 pulse which followed the E2 pulse by a fraction of a second created a longer duration of effect on the power lines and the connected grid. This pulse most likely lasted up to a minute and caused damage to an electrical supply and distribution systems along Con Edison's grid. The E3 pulse is particularly damaging to long-line infrastructure, of which consists of electrical cables and transformers. The E3 pulse caused by the lightning strike followed the E2 pulse and most likely accounted for the greatest direct damage along the grid (Carafano 2010, 3).

The two lightning strikes were around 18 minutes apart, each causing simultaneous flash overs of a pair of major transmission circuits, resulting in the faults of four power line faults. Con Edison had protective equipment in place prior to the strikes, however, they failed to properly automatically restore service to three of the four downed lines. This failure cascaded and directly contributed to the loss of additional transmission

circuits. Con Edison could not handle the rest of the New York City load, and automatically shut down its New York City network to preserve itself from overheating and being destroyed (Time Magazine 1977, 12, 17). The strategy of shutting down the New York Grid only worked for a few minutes, because the power drain resulted in overheating the neighboring Long Island Lighting Company's connected power lines. At 9:41 the city was completely powerless for 25 hours (Time Magazine 1977, 12, 17).

The social context of eight million people without power can encompass a multitude of different reactions, but one reaction commonly remained, disorder. With refrigerators quitting and air conditioners stopping in the middle of summer, the people had to do something. So they did, they opened doors and windows and went out into the streets. Without lights, pedestrians moved through the darkness looking for others with flashlights. With public transportation halted, people moved into the streets looking for a way home or to their loved ones. Manhattan's high rises were without water as their pumps had failed. Tenants had to resort to gathering water from fire hydrants below, or even more interesting boiling their own toilet water. Elevators were stuck in position across the city high rises, with many people trapped in them for hours. Electronic room locks at many hotels remained locked, and unable to open due to a lack of power (Newsweek 1977, 19-22).

With people out in the streets, lawless boredom kicked in resulting in mass looting and destruction. For 25 hours New York City remained under assault, as one lady put it to a police officer, "They are coming across Buskwick Avenue like buffalo!" Teenagers, grown men, old women, all together, punched out windows, disassembled window bar assemblies, shot locks off doors, and set ablaze anything they wanted to. In

the end, 2,000 stores were looted, at the cost of one billion dollars. Hundreds of people were hospitalized for injuries, 44 firemen were hurt fighting fires across thousands of locations. 418 police officers sustained injuries from getting assaulted by broken bottles, or hit with other projectiles. Police made 3,776 arrests swelling the prisons and the overflow prison. The 25,000 man police force could not stop the all-out insurrection, that lasting for 25 powerless hours (Newsweek 1977, 25-26).

Placing this event in a social context in relation to Foster's Infrastructural Stress Values this event is designated as, Very Destructive. With wide spread dis-organization, extreme levels of financial loss, and many injured, this event caused a considerable amount of stress on infrastructural and societal systems. The impact of the disaster created a historical event, which disturbed and frightened many. The stress level associated with this event is 100 on a scale of 1-200 (Foster 1976, 244).

#### Transportation Analysis

Highway transport was severely halted during the blackout, with the Metropolitan Transport Authority calculating 29 million dollars in lost revenue, and 6.5 million dollars in damages and overtime payments. There were clear changes in social transportation patterns with air travel a minor problem in comparison to motor and rail traffic.

According to the Metropolitan Transportation Authority on average 7.5 million transit trips are taken each weekday, they calculated 5.8 million transit trips were directly affected because of the blackout. The number did not reflect the millions of automobile trips which were indirectly halted due to inoperable gas pumps, the failure of traffic control devices, and mass pedestrian congestion. In addition to adding to pedestrian congestion, automobile congestion increased due to the subway systems parallel failure.

Subway riders resorted to their alternate means of transport, the automobile and got on the road compounding an already huge traffic problem (Corwin 1978, 50, 59).

All highway approaches into New York City experienced a decrease in traffic on the day of the blackout. For example the Lincoln tunnel experienced less than half of its normal traffic passing through. Bus transport also decreased slightly as reported as the bus companies reported fewer passengers. Since businesses were unable to operate, truck traffic declined directly reducing the amount of goods delivered across the city. Food, merchandise, and materials distributed in the city also decreased. With gas stations lacking power, customers were unable to receive fuel from underground stores. It should be noted that fuel would be a greater critical factor if the duration of the blackout extended beyond the 25 hours, as an automobile fuel tank can carry less than a week's worth of fuel on average under normal operation assuming the vehicle is not full. Some automobile drivers at the Kennedy Airport could not depart the parking structure since the ticket counters and gates were automatically and electrically controlled. The result was parking employees having to manually collect and raise the gates causing severe traffic jams and congestion for those seeking departure from the airport (Corwin 1978, 79-81).

A key staple of New York City is taxis, which were already fueled up and in good working condition prior to the blackout. While they were prepared for a normal day on the job they were not prepared for the masses crowding the streets. Without traffic signals operating they were also dodging each other in addition to a mass of pedestrians. The number of taxis declined overnight due to a number of factors to include, lack of fuel, drivers personally concerned for safety, and congestion (Corwin 1978, 83-89).



Through the 1977 blackout of New York City we see the direct impact two electromagnetic pulses of an EMP have on electricity and transport infrastructure. While automobiles, trucks, and buses were not directly affected by the lightning their capability was severely degraded due to the strikes second and third order effects. If this blackout occurred for longer than 25 hours, and in upwards of 72 hours the researcher would assert that the effect on transportation to be a total failure.

The largest transportation impact from the 1977 blackout was to railway operations, to include intercity rapid transit also known as the subway system. At the time the electrically based subway, rail system within New York City was the principal form of travel within the city. The subway system in New York City is closely integrated with automobile, commuter train, and bus means of transport. These means would be used in combination and concert to provide maximum efficiencies to the commuter. For example the majority of passengers who arrived in New York City by car, bus, or train would park on the city's edge and transfer to the subway and ride it into the city center to reach their destinations. Around three quarters of New York citizens either ride the bus or subway each day, therefore showing how vital rail transport is to the eight million citizens of New York City.

The Long Island Railroad typically transported 101,300 passengers to the city in the 1970s, while Conrail carried close to 72,000 from suburban communities to the city center. Both of these vital rail lines operated on electricity, and were shut down during operation due to the destructive second order effect of the electromagnetically charged lightning strike hitting Con Edison's lines. As a result of the subway's immediate shut down many passengers were stranded along the line, and those awaiting transport

switched to highway means. This mode switch created a significant impact to highway transport as highway congestion mounted. With pedestrians stranded they began walking, causing significant control problems between pedestrians and motor vehicle operators trying to navigate without control measures (Corwin 1978, 85).

With about a dozen Long Island trains stranded in Queens the transit authority had to use auxiliary power to move the subway trains into their stations so the passengers could debark. Seven trains remained non operable stranding several thousand passengers, of which two trains with hundreds of passengers were stranded on the Manhattan Bridge. Luckily the electromagnetic pulses which caused widespread electrical failure did not reach as far as the subway electronics infrastructure to create a permanent non operable condition for the entire system. The multiple subway control centers were affected by the lack of power, but were prepared with backup generators and largely remained unaffected. While the control centers were able to push emergency power to the some of the stranded trains, auxiliary power was not enough to light the dark subway infrastructure, specifically the station underground platforms. Some accounts recall panicked passengers emerging from the dark underground subway tunnels, confused, and somber (New York Times 1977, 1).

Like highway transportation, second and third order effects of an electromagnetic strike effected rail. These effects disrupted rail transport throughout the entire city and caused mass disorganization among those travelling by way of rail transit. While auxiliary power helped bridge a power gap for the rail center control, it only provided a short burst of electricity to create some emergency movement. For those stuck in a tunnel or on a bridge it was a 25 hour wait in a subway car, or gripping the tunnel walls in

complete darkness until an exit was found. At the hand of an electromagnetic strike the second order ramifications of total mass rail transit failure is seen in this case study, and even more troubling its direct third order effect on highway transportation failure is cause for increased concern.

From a SCADA perspective the combination of a natural lightning strike with E2 and E3 electromagnetically charged particles created a cascading effect that completely shut down the entire power grid of the Con Edison power company. The dual effect of a natural phenomenon and improperly operating protective SCADA devices resulted in a false common operating picture viewed by system dispatchers. The combination of these in addition to communication difficulties combined to create a cascading effect of total collapse of the Con Edison power system (Corwin 1978, 95).

The Con Edison grid had in place normal system protection to protect from physical intrusion or destruction that usually result from natural occurrences in a short amount of time. These programmable logic controllers and energy network protection devices make decisions on hundredths of seconds. Con Edison's system allowed human decision-making to get involved if the action could safely be conducted within minutes or hours. All other emergency actions were based upon preprogrammed logic, among physical devices like transformers and programmed logic controllers. In the case the 1977 blackout, the electromagnetic pulses caused by lightening disabled and or destroyed various SCADA devices which aimed at protecting the grid. The failure of these devices was not seen by human operators, and helped facilitate a further destruction of the grid (Corwin 1978, 25-27).

### Summary

The 1977 New York City blackout is a premier case study of what happens when electricity is lost in a metropolitan city. Not only did it show the effects of an electromagnetic pulse strike on an electrical grid, resulting in partial degradation and ultimate shutdown. It also showed the vast second and third order effects of a loss of power of transportation in a city that is totally reliant on electricity. The direct impact of SCADA systems caused a second order impact to rail transport, which intern creates a hugely compounding problem on highway transportation. If the blackout lasted more than 25 hours the researcher believes it would have substantially increased in infrastructural and societal stress, creating a disastrous event. A summary of the analysis is depicted in the table below.

Table 3. Table of Analysis, 1977 New York Blackout

Multiple Case Study Method		1960s Operation STARFISH PRIME	1977 New York City BLACKOUT	2003 North East BLACKOUT	* Kansas City (Impact Theory)
Criteria of analysis by category					
EMP	Type of EMP displayed (Manmade/Natural/Undetermined)	MANMADE	NATURAL		
	EMP type of pulse displayed (1,2,3)	1,2,3	2,3		
	Approximate size of known area affected (Miles)	1,600 Miles Rad.	350 Sq. Miles		
	Electrical grid damaged (Y/N)	Yes	Yes		
	Time of residual effect	4 Hours	25 Hours		
*	Event stress level (0-200)	10	100		
	Event designation	Moderate	Very Destructive		
Highway Transport	Local transport disruption (Y/N)	No	Yes		
	Physical movement disrupted (Y/N)	No	Yes		
	Traffic control measures operational (Y/N)	No	No		
	Automobile/Trucks disabled (Y/N)	No	No		
	Traffic Operation Centers Disrupted (Y/N)	N/A	Yes		
	Traffic congestion impeding flow of transport (Y/N)	No	Yes		
	Number of highway vehicle accidents reported	UNK	UNK		
Rail Transport	Rail transport disruption (Y/N)	No	Yes		
	Rail Control Center disrupted (Y/N)	No	Yes		
	Rail traffic control measures operational (Y/N)	UNK	Yes		
	Rail prime movers disabled (Y/N)	No	Yes		
SCADA Systems	SCADA control systems damaged or disabled (Y/N)	Yes	Yes		
	Electrical transmission distribution disrupted (Y/N)	Yes	Yes		
	Sensor system disruption (Y/N)	No	Yes		
	Sensor system level of failure (PLC/RTU/ECU)	N/A	PLC/ECU		
	Pipeline distribution disrupted (Y/N)	Yes	Yes		
	Cascading SCADA system failure displayed (Y/N)	Yes	Yes		

\* Infrastructural Stress Value Data
   Correlation within category
   Confirmation of effect

\* Impact Theory applied in CH 5, Findings

Source: Created by author with two integrated categories developed by Harold D. Foster, "Assessing Disaster Magnitude: A Social Science Approach," *The Professional Geographer* 28, no. 3 (1976): 244.

### Case Study: 2003 Northeast Blackout

#### Introduction and EMP analysis

The 2003 Northeast blackout occurred on 14 August 2003 at 4:00 in the afternoon impacting the entire Northeast power grid and causing more than 50 million people in the U.S. and Canada to lose power. Power was restored to some within hours while others had to wait two days, and in the case of Ontario two weeks. The blackout's origins were traced by the U.S. -Canada Power System Outage Task Force to a combination of

cascading failures. One failure of note is that First Energy, a power company responsible for many of the failures did not have a proper situational understanding or awareness of their grid. Therefore, it can be reasonably assumed that the exact reason or overarching contributing failure remains largely unknown. Without an exact known failure, a lack of situation awareness and understanding by those responsible, one cannot rule out possible electromagnetic interference as a potential contributing factor against a grid covering the vast geography of north east America and southeast Canada (U.S.-Canada Power System Outage Task Force 2004, 5). As indicated by the Task Force, striking similarities occurred to earlier historical blackouts to include the New York Blackout of 1977. Efforts to implement earlier power grid recommendations and lessons learned were not adequate and were not fully implemented by the privatized power companies. (U.S.-Canada Power System Outage Task Force 2004, 139).

An area of 3,700 square miles was without power due to failed transmission lines which directly led to power spikes and drains throughout the area. As seen in the 1977 blackout, when power plants, generators, and connected electrical infrastructure systems sense a potentially destructive environment they shut themselves down for preservation. This cascading shutdown or disabling effect is exactly what happened during the blackout of 2003. Similarities were present between the 2003 blackout and the 1977 blackout when viewing them from a New York City perspective. Economic tolls were enormous for two countries, totaling an average of between four and six billion. Unlike 1977, New York City's post-9/11 security paid off as the city avoided the mass looting and pillaging of decades earlier. The city also just experienced the events of 9/11 and was experienced at disaster response and stress mitigation measures.

Applying Foster's Infrastructural Stress Value to this disaster would designate it as, Very Pronounced. It holds the designation primarily due the number of people affected at over 50 million people. Secondly, many people were frightened due to the event, which they immediately thought was an act of terror. The event created a significant economic impact in society and infrastructure. Lastly the magnitude of the event left many remembering and etched its place in history. The 2003 northeast blackout's sheer area of effect across two countries show a vast multi-national inter-dependence on electricity with vulnerable infrastructure. The cascading effect of system of systems creates a large vulnerability to overcome if not properly executed.

#### Transportation analysis

This transport analysis specifically focuses on New York City and the event on a regional level due the large scope of a 3,700 square mile effected area. Roughly half of New York citizens owned an automobile in 2003, and around two million registered vehicles. The New York mass transit ridership topped nine million passengers per weekday. There were 11,600 traffic control signals throughout the city in 2003, with 6,000 of them computer controlled from the city-operated Traffic Management Center within a Joint Transportation Operation Center. Similar to 1977, mass transit continued to be a major mode of efficient transport for citizens. Computer controlled signals shows a departure from old 1977 dated technology (Volpe 2004, 4, 6-7).

On the day of the blackout the highway and rail systems lost power resulting in all signalized traffic control measures to lose power at the same time. In addition, those signals and sensors were no longer connected to the Traffic Management Center. All 413 trains navigating the New York City subway system lost power, stranding over 400,000

people. The electrified commuter rail also shuts down, disconnecting the greater regions of New Jersey, and Connecticut. 300 miles of intelligent transportation systems were unable to function due to a loss of power. Some of the systems included variable message roadway signs, highway advisory radio systems, embedded sensors, and communication systems. The New York City traffic management center was also without power for three hours, unable to control traffic flow (Volpe 2004, 17).

Like the 1977 blackout, the highways again became overcome by pedestrians and vehicles as mass transit failed. Workers could not work so they either walked home or took their vehicles. Emergency responders were overwhelmed with rescue calls of people stuck in elevators like 1977. Traffic controls were inoperable bringing the pedestrian and vehicle movement to a halt. All subway, commuter rail, and light rail systems in the New York region depended upon electricity and subsequently shut down. Unfortunately the subway did not have an automated vehicle locator or emergency lighting in tunnels, both making evacuation harder. Bus transportation was also compromised as their communications were shut down at their command and control centers, which lacked power and led to mass disorganization (Volpe 2004, 29).

### Summary

The city built up resistance to disasters over time, and used its experience of the 1965 and 1977 blackouts, 11 September 2001, and Year 2000 to mitigate total disaster. Technology increased at a more rapid pace than that of the experience gained creating a void of knowledge as it related to current state technology. For instance SCADA devices developed tenfold since the 1977 blackout and with an increase in technology comes a greater dependence on electricity in a redundant nature. While one cannot confirm if an



EMP was even present in this disaster, the exhibited effects closely relate with retrospect to the other case studies presented in this analysis. Regardless of whether an EMP effected New York City's transportation infrastructure one could deduce that transportation infrastructure is vulnerable to a loss of electricity, that of which an EMP could affect. The 2003 blackout caused outages throughout all of the major modes of transportation and was widely felt through the entire northeast region. A summary of the analysis is depicted in the table below.

Table 4. Table of Analysis, 2003 North East Blackout

Multiple Case Study Method		1960s Operation STARFISH PRIME	1977 New York City BLACKOUT	2003 North East BLACKOUT	* Kansas City (Impact Theory)
Criteria of analysis by category					
EMP	Type of EMP displayed (Manmade/Natural/Undetermined)	MANMADE	NATURAL	UNDETERMINED	
	EMP type of pulse displayed (1,2,3)	1,2,3	2,3	N/A	
	Approximate size of known area affected (Miles)	1,600 Miles Rad.	350 Sq. Miles	3700 Sq. Miles	
	Electrical grid damaged (Y/N)	Yes	Yes	Yes	
	Time of residual effect	4 Hours	25 Hours	2 Hrs-4 Days	
*	Event stress level (0-200)	10	100	65	
	Event designation	Moderate	Very Destructive	Very Pronounced	
Highway Transport	Local transport disruption (Y/N)	No	Yes	Yes	
	Physical movement disrupted (Y/N)	No	Yes	Yes	
	Traffic control measures operational (Y/N)	No	No	No	
	Automobile/Trucks disabled (Y/N)	No	No	No	
	Traffic Operation Centers Disrupted (Y/N)	N/A	Yes	Yes	
Rail Transport	Traffic congestion impeding flow of transport (Y/N)	No	Yes	Yes	
	Number of highway vehicle accidents reported	UNK	UNK	UNK	
	Rail transport disruption (Y/N)	No	Yes	Yes	
	Rail Control Center disrupted (Y/N)	No	Yes	Yes	
	Rail traffic control measures operational (Y/N)	UNK	No	No	
SCADA Systems	Rail prime movers disabled (Y/N)	No	Yes	Yes	
	SCADA control systems damaged or disabled (Y/N)	Yes	Yes	Yes	
	Electrical transmission distribution disrupted (Y/N)	Yes	Yes	Yes	
	Sensor system disruption (Y/N)	No	Yes	Yes	
	Sensor system level of failure (PLC/RTU/ECU)	N/A	PLC/ECU	PLC/ECU/RTU	
	Pipeline distribution disrupted (Y/N)	Yes	Yes	Yes	
	Cascading SCADA system failure displayed (Y/N)	Yes	Yes	Yes	

\*

Infrastructural Stress Value Data

\*

Impact Theory applied in CH 5, Findings

Correlation within category

Confirmation of effect

Source: Created by author with two integrated categories developed by Harold D. Foster, "Assessing Disaster Magnitude: A Social Science Approach," *The Professional Geographer* 28, no. 3 (1976): 244.

## Kansas City

### Introduction

President Dwight Eisenhower, a native of Abilene, Kansas selected Kansas City as one of the first areas to receive interstate highways. It used the opportunity to develop its self as one of the U.S.'s top tier transportation and distribution hubs. Kansas City is the most centrally located major U.S. transportation hub. The bi-state 18 county region

features all major modes of transportation and offers vital supply chain assets through multi-modal means. As the most geocentric U.S. city it is essentially the heartbeat of major distribution corridors in North America. Low transportation costs within the area paired with a wide range of logistics options are a significant factor in the rapid expansion of its industry sector (Trunick 2007, 1). To maintain a top tier status Kansas City has also continued to improve upon technological enhancements to transportation through intelligent highway systems, mass transit efficiencies, and a heavy reliance on electronically controlled SCADA devices.

### Transportation Analysis

The largest rail center by tonnage in the U.S. resides in the bi-state Kansas City area, and is the focal point of a rail corridor spanning from coast to coast and Mexico to Canada. Multiple major interstate highways (I-35, I-70, I-29, I-49) run north to South and East to West through Kansas City helping to identify it as the third largest trucking center in the U.S. Within the K.C. region there are four top tier intermodal logistical distribution centers, which are; Northland Park, KCI Intermodal Business Center, Center point Intermodal Center, and Logistics Park. In addition, numerous fortune 500 companies, retailers, and importers have distribution centers located throughout Kansas City. Kansas City lies at the heart of the U.S. and North American transportation corridor (Trunick 2007, 3). The illustration below depicts tonnage by mode throughout the U.S. This figure reinforces Kansas City's important geographic location, while displaying the vast interconnections and volume of rail and road tonnage transiting the Kansas City Area.

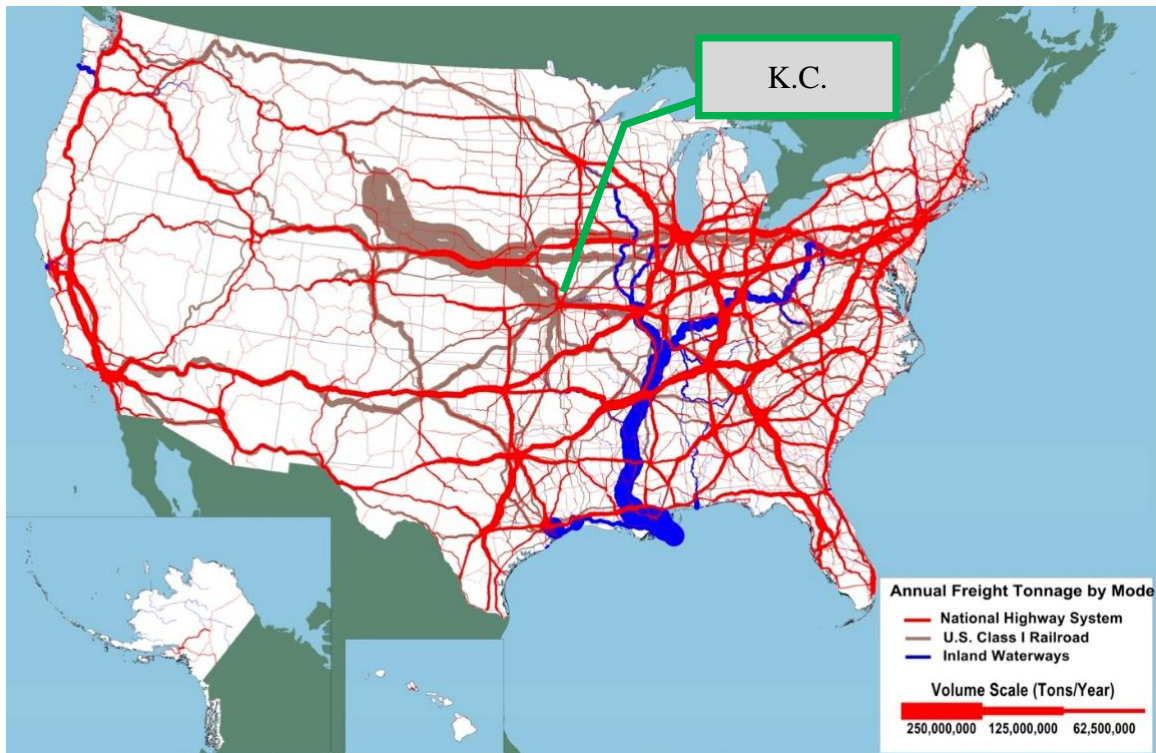


Figure 4. Tonnage on Highways, Railroads, and Inland Waterways: 2007

*Source:* U.S. Department of Transportation, “Tonnage on Highways, Railroads, and Inland Waterways: 2007 Map,” National Statistics and Maps, [http://www.ops.fhwa.dot.gov/freight/freight\\_analysis/nat\\_freight\\_stats/tonhwyrww2007.htm](http://www.ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/tonhwyrww2007.htm) (accessed 14 May 2014).

Kansas City is one of the largest railroad hubs in the U.S. with well over 225 miles of track in its jurisdiction. Kansas City Terminal Railway Company provides command and traffic control for major railroads to well over 300 daily arrivals and departures (Trunick 2007, 2). The most heavily traveled lines cross through downtown Kansas City and other densely populated areas. The largest local railroad operators are Union Pacific with 165 trains per day, and Burlington Northern Santa Fe, with 125 trains per day transiting the Kansas City area (The Office of Emergency Management for Kansas City 2008, 4). Railroad officials estimate well over 600 rail cars pass through

Kansas City each day carrying hazardous material of various types and compatibilities (The Office of Emergency Management for Kansas City, 5).

President Eisenhower's commitment to the area in the form of the interstate highway system directly contributed to Kansas City's honor among the top ten U.S. transport metro areas. Combining Kansas and Missouri miles of highway in the Kansas City area are an estimated 2,000 miles of road. The city has more freeway lane miles per capita than any other U.S. city, and one of only five cities with five intersecting interstate highways (Trunick 2007, 10). Similar to rail transport, Kansas City's geographic location sits on the nation's highway cross road, and is a major hub for local, regional, and national transit. The local road system includes more than 197 miles of highway, including seven interstate highways, and various state highways between Kansas and Missouri (Trunick 2007, 3).

Between Kansas and Missouri they have a total of less than 20 employees to monitor and oversee and average of 823 dams, across both states. Kansas alone has 9 employees monitoring an average of 668 dams, with numerous SCADA systems accounting for a some of the oversight. Missouri has 1,588 high hazard dams and Kansas has 230. While Kansas has an emergency action plan for 81 percent of all their dams, Missouri only has an emergency action plan for 43 percent (American Society of Civil Engineers 2013a, 1).

Kansas City's water treatment plant produces 240 million gallons of water each day. They transport those gallons by way of 2,800 miles of water mains and distribution systems. While they still use some of the same water mains installed in 1894, a majority of them are upgraded to modern specifications, including SCADA systems to help

control water regulation. To control wastewater or sewage Kansas City has six wastewater treatment plants with around 2,800 miles of wastewater pipeline. Kansas City maintains the nation's third longest urban levee system, which uses SCADA and other electronic devices to control and monitor their water works system. Their storm water system extends over 300 square miles and includes 35,000 storm inlets to mitigate flooding. Kansas City, sitting on the Missouri river is well aware of the potential for catastrophic flooding, and uses SCADA computer systems to control their water systems. (City of Kansas City, Missouri 2014, 1).

In and around Kansas City four coal power plants exist, with two natural gas plants, and a petroleum power plant within a ten mile radius of the city. The closest nuclear power plant resides in Wolf Creek, Kansas, approximately 65 miles South West from Kansas City's center. 20 miles North of Kansas City proper, the St. Joseph landfill generating power from its biomass power plant. All of these power plants use SCADA systems in some form or fashion, and vast arrays of electrical computerized components which help them produce and distribute power to the greater local area. The figure below depicts the sheer scope of energy in differing forms that pass through or are fixed sites within the Kansas City area.

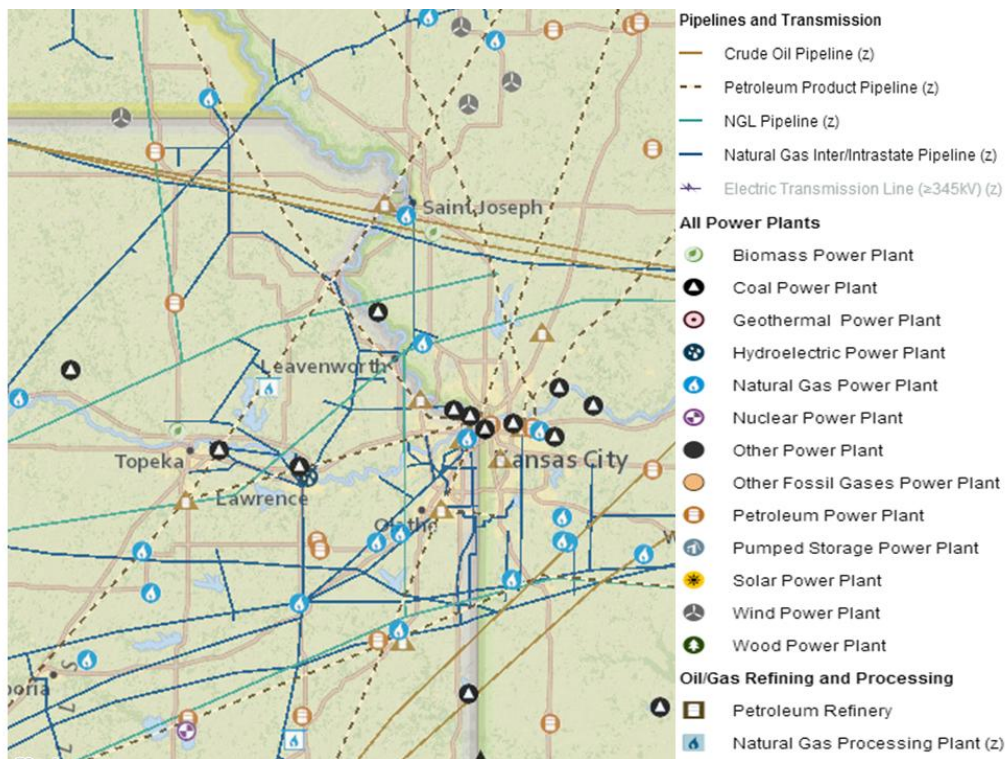


Figure 5. Kansas City Energy Infrastructure Map

Source: U.S. Energy Information Administration, “U.S. Energy Mapping System,” <http://www.eia.gov/state/maps.cfm?v=Energy%20Infrastructure> (accessed 4 February 2014).

With Kansas at the mid-continent center it is a key natural gas supply hub that takes production from several states and pipes it to the east coast for consumption. In addition, it ranks ninth in the nation in crude oil production for 2011 (U.S. Energy Information Administration 2014a, 1). Specifically, within the greater Kansas City area two crude oil pipelines run east and west ten miles north, while another two major crude oil pipelines run south of Kansas City by 20 miles. Hundreds of miles of natural gas pipeline run around and through the Kansas City area, most of which service the city. Numerous petroleum pipelines run in and out of the city servicing the city as well as the

surrounding communities. In addition, three hazardous liquid pipelines run north and south of Kansas City, within ten miles of the city center (U.S. Energy Information Administration 2014a, 2).

### Summary

Kansas City is a key multi-modal transportation hub centered on the North American continent, highly dependent upon electricity to drive operations. Not only does it require energy for transportation operations in and around the city, but energy also flows through the city as part of a vast interconnected system. Kansas City, while dependent upon itself also provides numerous resources and goods to the larger American region. Kansas City's highway system intelligently connects the east and west coasts, while facilitating a large degree of energy driven rail and pipeline operations in support of the greater region, and nation.



## CHAPTER 5

### FINDINGS AND CONCLUSIONS

#### Findings

Table 5. Table of Findings, Kansas City Impact Theory

Multiple Case Study Method					*
Criteria of analysis by category					Kansas City (Impact Theory)
EMP	Type of EMP displayed (Manmade/Natural/Undetermined)	MANMADE	NATURAL	UNDETERMINED	
	EMP type of pulse displayed (1,2,3)	1,2,3	2,3	N/A	
	Approximate size of known area affected (Miles)	1,600 Miles Rad.	350 Sq. Miles	3700 Sq. Miles	
	Electrical grid damaged (Y/N)	Yes	Yes	Yes	
	Time of residual effect	4 Hours	25 Hours	2 Hrs-4 Days	
*	Event stress level (0-200)	10	100	65	65
	Event designation	Moderate	Very Destructive	Very Pronounced	Very Pronounced
Highway Transport	Local transport disruption (Y/N)	No	Yes	Yes	Yes
	Physical movement disrupted (Y/N)	No	Yes	Yes	Yes
	Traffic control measures operational (Y/N)	No	No	No	No
	Automobile/Trucks disabled (Y/N)	No	No	No	No
	Traffic Operation Centers Disrupted (Y/N)	N/A	Yes	Yes	Yes
	Traffic congestion impeding flow of transport (Y/N)	No	Yes	Yes	Yes
	Number of highway vehicle accidents reported	UNK	UNK	UNK	N/A
Rail Transport	Rail transport disruption (Y/N)	No	Yes	Yes	Yes
	Rail Control Center disrupted (Y/N)	No	Yes	Yes	Yes
	Rail traffic control measures operational (Y/N)	UNK	No	No	No
	Rail prime movers disabled (Y/N)	No	Yes	Yes	No
SCADA Systems	SCADA control systems damaged or disabled (Y/N)	Yes	Yes	Yes	Yes
	Electrical transmission distribution disrupted (Y/N)	Yes	Yes	Yes	Yes
	Sensor system disruption (Y/N)	No	Yes	Yes	Yes
	Sensor system level of failure (PLC/RTU/ECU)	N/A	PLC/ECU	PLC/ECU/RTU	PLC/ECU/RTU
	Pipeline distribution disrupted (Y/N)	Yes	Yes	Yes	Yes
	Cascading SCADA system failure displayed (Y/N)	Yes	Yes	Yes	Yes

\* Infrastructural Stress Value Data
  Correlation within category
  Confirmation of effect

\* Impact Theory applied in CH 5, Findings

Source: Created by author with two integrated categories developed by Harold D. Foster, "Assessing Disaster Magnitude: A Social Science Approach," *The Professional Geographer* 28, no. 3 (1976): 244.

Imagine a man-made thermonuclear tipped missile launched off a hallowed out "SCUD Tub" cargo freighter in international waters off the pacific coast. It travels into the upper atmosphere and its launching pad, the ship platform, is scuttled to avoid

identification. The thermonuclear device is detonated in the upper atmosphere over Kansas City before the U.S. can counter it, creating an EMP effect as electrically charged particles fall through the atmosphere back to Earth. Or perhaps the Sun emits a solar flare during a heightened solar cycle. The flare contacts the Earth's atmosphere over Kansas City creating electromagnetically charged particles that fall over the city in the form of an Aurora Borealis. Either a man-made or natural EMP strike in the atmosphere over Kansas City would produce an almost unimaginable devastation. Due to Kansas City's central U.S. geographical location and man-made EMP detonated at the right height above, it could strike nearly every state in the U.S. Communication would collapse, transportation would halt, and the city would be in a state of blackout. Kansas City would be in complete darkness.

An EMP would heavily damage Kansas City's transportation infrastructure which relies upon just-in-time logistics. As Kansas City competes with other cities across the nation, it turns to lowest cost, best performance practices amongst its infrastructure. These practices not only provide cost savings, but also create huge technological dependencies to track, reroute, and expedite goods. Just-in-time logistics relies upon the technologically advanced transportation infrastructure to rapidly respond to demand. Kansas City's transportation infrastructure is highly reliant upon remote tracking, data processing, transportation management, communication, computer control, and uninterrupted movement. Most of the technology in Kansas City's transportation infrastructure is electronics based, therefore vulnerable to a natural or man-made EMP strike. Any disruption or degradation of Kansas City's transportation infrastructure will likely impact response and recovery efforts during the disaster. Kansas City's

transportation is crucial in providing life sustaining goods and services, not only to the local population, but also to the larger region.

The developed impact theory shows that an EMP strike either man-made or natural against Kansas City will produce a Very Pronounced event, in accordance with Foster's Infrastructural Stress Values. This type of incident would produce a stress value of 65 on a scale of 1 to 200 to the people and infrastructure of Kansas City. The initial amount of stress would disturb and frighten citizens while creating a historical event for many years. An EMP strike against Kansas City would compound the stress on infrastructure and people over time. As seen with both New York blackout cases, as time increased, second and third order stress effects are multiplied. If Kansas City is affected by a blackout for more than 24 hours its citizens and infrastructure stress will double and intern produce fatalities, panic, and heavy financial loss. If Kansas City remains blacked out for more than 72 hours, a potentially disastrous event could occur as fatalities will mount due to injury, structural collapse, and widespread disorganization. Kansas City's mid-sized class averages three days of food supply, and without transportation the people of Kansas City will go hungry the longer a blackout remains in effect. Without this basic necessity people will take action into their own hands further compounding the stress of the disaster over time.

Kansas City's multiple major interstate highways (I-35, I-70, I-29, I-49) will be largely congested. As seen with all three case studies, a EMPs effect will disable traffic controls along highways and interstates creating disorganization and massive traffic congestion. This problem will increase by all of the population being affected at nearly the same time. Interstate off ramp traffic control measures will malfunctioning creating a

traffic backlog at off ramp intersections, which will spill halted traffic onto a 70 mile per hour freeway increasing the potential for fatal traffic accidents. Real potential exists for fatal accidents to occur across Kansas City's interstate highways due to an EMP strike disrupting intelligent highway systems and control measures.

With current technology one could assume cell phone towers would go down in the area due to a lack of power, creating even more disorganization among the population whom are dependent upon their cell phones. With ground transport disrupted those looking to get home as quick as possible to help loved ones may find themselves resorting to walking. Without functioning traffic lights, pedestrians and vehicle operators will find themselves de-conflicting priorities, slowing down movement. The one single traffic operation center in Kansas City will find itself swamped with land line calls if the phones work, and will be unable to maintain situational understanding and awareness to effectively command and control. Traffic cameras throughout the city will cease to function, overpass signs will cease operation or if solar controlled will not display up to date data provided by the control center.

The highway situation will compound over time as a citizen maintains on average a week's supply of fuel in their vehicle under normal operation. Fuel will remain in on hand stock throughout the city, however gas stations will be unable to pump fuel from their underground tanks. Leaving vehicle operators empty or having to travel out of the area, while expending extra fuel to get there. The lack of fuel will bring general transportation to a halt, turning people turn to pedestrians. This will further add to the confusion and congestion on the streets.

None of the case studies illustrated the direct effect of an EMP strike on a vehicle. In a natural scenario such as lightening, the lightening would have to directly strike the individual vehicle to render it inoperable. The EMP Commission conducted man-made simulation testing as well as other private companies, suggesting 30 percent of vehicles will either suspend operation for a brief second or rendered inoperable and in need of replacement parts. Kansas City's motor vehicle operators may lose control of their vehicles during an EMP strike due to a lack of power. Steering wheels may lock up due to electrically charged power steering pumps shutting down. This will send drivers careening down the roads in upwards of 70 miles per hour without a way to direct their multi-thousand pound vehicles. With many bridges and overpasses in Kansas City accidents will happen within their narrow corridors during an EMP event, potentially sending uncontrollable vehicles and their operators into the depths of the Missouri river. An EMP strike will create just enough chaos and disorganization amongst vehicles to create a highway disaster throughout the city.

The disruption to highway transport in Kansas City is significant, and will only get worse the longer it is disrupted. Intelligent Highway Systems will be effected, and unable to function, creating a degree of uncertainty and further complicating traffic congestion. Disorganization among man and machine will prove to be the largest problem for Kansas City trying to combat a number of problems. A significant third order effect of highway transport being disrupted is the impact of the city's external and internal transportation of critical supplies such as water. These goods will have a problem entering or exit the city, and workers will be unable to transport them around the city as business will be closed and unable to function. This will leave the mass of Kansas City to

boil their own water as pumping stations remain without energy. Hospitals in and around Kansas City will only have on hand supplies available due to malfunctioning resupply trucks or the lack of drivers to operate them.

Rail transport in Kansas City will experience a disruption due to a loss of power from an EMP strike. Specifically, the Kansas City Terminal Railway Company will lose the ability to command and control its smart railways. The provider will lose the ability to implement traffic control measures, change lanes, and effectively communicate with conductors. Even with backup generating methods, any gap in situational awareness and understanding could lead to an accident, with 600 trains transiting the Kansas City area daily. Some of these trains contain hazardous cargo, and if in an accident could create a hazardous material disaster inside the city.

Railway traffic and congestion will build up, like highway transport, and will compound over time. Unable to command and control the railway network will create an inability to unclog the mounting railway traffic jam. The degradation of an average 300 train arrivals means exported and imported goods will not be transferred, causing the industrial sector to collapse, and shutdown work. This shutdown will create an economic impact to the company and individuals employed by the company. With price gouging a normal occurrence during a disaster, and employees unable to work, the local economy will become a severe flashpoint among the citizens of Kansas City.

Union Pacific and Burlington Northern Santa Fe will take the brunt of the rail disruption as they are the largest users in the area. With the rail control center disabled, no one would have ultimate control of over 600 trains passing through each day, unable to de-conflict priorities, change lanes, and combat problems. The impact to Kansas City's

railways creates a greater regional problem as high demand goods like coal and oil will either have to be rerouted or stuck in a massive railway jam. If these resources are unable to reach other cities across the U.S., the EMP strike's impact could create a wider spread blackout situation due to a lack of energy producing resources.

As seen through all three case studies, SCADA systems are extremely susceptible to an EMP strike if not protected properly. In the case of a man-made strike, the effect would destroy any protective devices, leaving a vulnerable network to the resulting destructive pulses. Those pulses would destroy or disable programmable logic controllers, electronic control units, and remote terminal units. In the event of a natural strike, if not properly protected, SCADA devices could be damaged. Like in both blackout case studies a cascading second order effect would most definitely occur in Kansas City. The result of a cascading effect would most likely shut down power plants in the area to include the nuclear power plant at Wolf Creek. These power plants would shut down in order to preserve themselves. Oil, gas, and hazardous pipelines would become unregulated and the resulting free flow would automatically trigger a shutdown of their lines. This result could potentially create a hazardous spill, leak, or reduce the flow of critical goods to a regional area.

Satellites providing line-of-sight global positioning guidance to SCADA and transport infrastructure systems will be disrupted and or destroyed permanently. The loss of global positioning creates a real threat to ground based just-in-time transportation. Truck and locomotive operators may not know exactly where they are going or how exactly to find their final destinations. The loss of GPS will negatively affect pipelines across Kansas City, which are regulated by SCADA controllers. These controllers will

stop regulating the network inherently creating pipeline congestion, which could lead to overpressure and a rupture of the pipes. Some of the pipelines in Kansas City transport hazardous material and could create a hazardous material disaster in and around the city. This will further complicate response and recovery, while compounding stress on infrastructure and citizens.

Electrical transmission lines will become overcharged in the event of a man-made or natural EMP strike. The resulting effect would blow or trip transformers across the city. The power provider would not see any transformer trip or transmission anomaly, because their remote sensors would also fail as a result of the strike. Kansas City's electrical grid would sustain significant damage. Recovery efforts will not be immediate as any repair parts not on hand in the City's stock will most likely be procured from overseas. The result of a loss of SCADA systems will create a cascading effect, possibly effecting the automatic shutdown of the Nuclear power plant at Wolf Creek, Kansas. With the electrical grid sustaining damage in Kansas City, other regionally connected SCADA systems may try to over-correct this anomaly. Their automated over correction could internally damage the same grid they were built to regulate and protect. Other connected power plants across the regional grid may initially automatically shut down to preserve themselves, thus leading to a greater regional blackout.

Across SCADA systems, and transportation infrastructure major effects will be felt by an EMP strike. The largest problem besides the lack of power is disorganization within transportation systems. This disorganization will increase and compound damage over time if not acted on immediately. The effect on Kansas City will create fatalities, damage, destruction, while creating a lasting effect on a regional scale. While it won't



exhibit the magnitude of a catastrophic event initially, if not properly responded to, overtime will devastate the greater Kansas City region.

### Conclusions

To conclude the primary research question was how will an Electromagnetic Pulse (EMP) strike targeting a mid-size city such as Kansas City affect its road and rail based transportation distribution infrastructure? A strike, be it a well-placed natural or man-made EMP will halt Kansas City's transportation for an indefinite amount of time. The longer the effect is present the more damage, destruction, and disorganization it is going to cause. If the blackout effect lasts for more than 24 hours in Kansas City the destruction and infrastructural stress will double. If longer than 72 hours an EMP's blackout effect will multiply, creating a disastrous situation in Kansas City, while furthermore damaging the greater region of Kansas City.

To answer the secondary question of what are the second and third order effects if a city's transportation and distribution networks are shut down? The second, third, and fourth order effects are the most troubling in relation to an EMP strike. While the direct effect of an EMP will not create fatalities, the residual effect of an EMP on transportation could create a significant loss to people and infrastructure. The indirect effects caused by an EMP create a void between mankind and its technological linkage. This breakdown is increasingly significant in a world ever more reliant upon electricity and technology. The indirect effects could create regional instability, and cause a void which would consume numerous resources to fix immediately. As opposed to the devastation of the direct strike nuclear device, an EMP would still leave the population to fend for itself, without

infrastructure. This situation would create a need for immediate action from the local, state, and government to respond and recover.

#### Areas for further research

Many areas exist for further research as this topic is underdeveloped among the unclassified community. Inter-regional study on a EMPs effect would provide a broader perspective across communities, and identify vulnerable interrelated, and interconnected systems. A greater understanding of how an EMP strike will directly affect vehicles and locomotives could provide a greater knowledge base of understanding to the community. The researcher believes greater automotive and locomotive data exists in a classified domain.

A few significant areas of research were present when looking at third and fourth order effects of an EMP. The first area requiring further research is understanding the effects of food stock age within a city, and the resulting effect of a food shortage within a city. This data would provide the community a broader base of knowledge into human needs during a disaster, while providing data to build a response off of. Another area of future research is to identify the effects of an EMP strike on air transportation. The U.S. and the world are greatly reliant upon air transportation to conduct various time critical activities, and the researcher would assume any delay or degradation of air transportation in the U.S. would affect the world. Understanding the effects could assist in providing a complete transportation picture of a EMPs effect as air transport is vital to multi-modal operations, economic business activities, and just-in-time logistics.

While the National Response Framework has an incident annex for nuclear and biological, it does not specifically direct a coherent response to an Electromagnetic Pulse

strike. Further research should be conducted on how to best respond to an EMP event, and furthermore, how it fits into the National Response Framework. An EMP event is not the same as a Nuclear Strike, even though they may both be nuclear devices, the effects are different. Therefore the response for an EMP should not be categorized or responded to as a stand-alone nuclear event. In addition, research should be conducted on how a lack or degradation of transportation capability will affect the National Response Framework's ability to respond and recover across all Emergency Response Functions.

A starting point for how to respond to an EMP disaster could come from the emergency responder's After Action Reviews during historical blackouts or a City's standard emergency response procedures. Further research into historical blackouts within a city or region could strengthen the knowledge of an EMP's indirect effect and provide more basis for analysis. Likewise, research gained on an EMP's effect and response to it could be used to help local communities plan for a blackout scenario. If a community is prepared to respond to an EMP strike, they more than ready for a blackout.

### Summary

An EMP strike is a relevant threat to the social and technological fabric of daily life. If one could imagine a day without electricity, and the resulting effects, one could understand how an EMP can affect a population. As the U.S. remains more and more dependent on technology, and transportation it also remains increasingly vulnerable to electrical attack. Transportation interconnects the world, and in conjunction with electricity makes a people's way of life possible. With transportation infrastructure becoming more interconnected and interdependent, the transport industry will continue to increase its dependency on electrical components and technology. As this dependency

mounts, it becomes more likely that electrical system failures could result in more widespread disruptions among different modes within the transportation infrastructure. Without transportation is to be without food, water, and modern shelter. To be without electricity is to be cold, dark, and powerless. The combination of these failures results in a devastating impact to the transportation within Kansas City, resulting in more than a half a million people, scared, hungry, immobile, and demanding help.

Kansas City and U.S. transportation infrastructure could benefit from ongoing federal cyber research and development initiatives to improve the security of transport infrastructure from an EMP or general blackout event. The federal and private transportation sectors should leverage research and development from private energy providers, as this sector is also significantly vulnerable to a man-made or natural EMP strike. The private, public, and federal transport sectors should closely coordinate on best practices, planning, and prevention.

The general public needs to be aware of the effects of an EMP strike so they can prepare accordingly. A national awareness program could facilitate communication of this threat and help to educate citizens on what it is, how it occurs, and how to respond. The lowest level of disaster response is within the individual person, therefore every person should at least be aware that this threat exists, so they can determine how to best prepare themselves and their families to protect against the nation's greatest sleeping giant.

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